3.6 GROUNDWATER HYDROLOGY

SYNOPSIS

This section examines the subsurface hydrology, or groundwater, of the proposed project area. While all three proposed project components interact with groundwater to some degree, the proposed mine site would alter groundwater hydrology in and around the mine. The section looks at applicable laws, hydrogeology (literally, water in the earth), and existing uses of groundwater, before turning to expected effects. Discussion and analysis of groundwater quality can be found in Section 3.7, Water Quality.

Summary of Existing Conditions:

Regulatory Framework: A number of federal and state regulations, including the Safe Drinking Water Act, and portions of Alaska Administrative Code, including Temporary Use Authorizations, pertain to groundwater for the proposed project.

Mine Site: The proposed mine and processing facilities would be located in a region of localized discontinuous permafrost. In this region, groundwater occurs both above and beneath the permafrost, and in permafrost-free areas. Groundwater feeds area streams during dry conditions and in winter months, and is recharged through snowmelt, rainfall, and stream flow. Mine site groundwater is in three main units: an alluvial aquifer associated with Crooked Creek; a thin, colluvial layer associated with valley slopes and bottoms; and, in bedrock aquifers. Analysis of stream discharge records from Crooked Creek indicate that the creek generally gains water from groundwater in the area of the proposed mine site.

Transportation Facilities: Along the Kuskokwim River, considerable groundwater is found in alluvial deposits amid alternating layers of sand and gravel and silty deposits up to hundreds of feet thick. Permafrost can be up to 400 feet thick in places along the river, with groundwater sometimes present above and below. Wells provide water to many households in villages along the Kuskokwim. In Bethel, well water is drawn from below permafrost, while other communities use shallower aquifers. On a regional scale, groundwater flow systems in the Kuskokwim River corridor tend to flow to the southwest. The year-round flow of the Kuskokwim River and its major tributaries is attributable to groundwater discharge to the rivers throughout the winter months.

Pipeline: Along the proposed pipeline corridor, groundwater occurs: in the Cook Inlet aquifer system; in alluvial, colluvial, and glacial deposits, and bedrock of the Alaska Range; and, west of the Alaska Range, in alluvial deposits and above permafrost. Approximately 35 percent of the proposed pipeline route is estimated to be underlain by shallow groundwater (within 3 feet of the land surface) during summer, or by substantial wet organic deposits.

Groundwater Flow and Modeling: A three-dimensional, mathematical model of roughly 85 square miles surrounding the proposed mine site (to a depth of 1,500 feet below the deepest proposed mine area) was constructed based on the location of major surface and groundwater divides in the vicinity, using field measurements and field-based estimates for water inputs, outputs, and underground structure. This modeling is the basis of estimates of the effects of the project on groundwater hydrology. In a process of calibration, the model was tested against past data, yielding results within accepted groundwater modeling industry standards.

Expected Effects:

Alternative 2: Donlin Gold's Proposed Action – The proposed mine would lower the water table in the area of and around the proposed pit in order to establish stable pit walls and dry working conditions. This *dewatering* would be accomplished by pumping groundwater from wells and drains in the pit area for use in the processing mill and for treatment and return to Crooked Creek. The deepening and lowering of the water table would form a *cone of depression*, which would continue through the life of the mine. Water levels in the bedrock aquifer would be lowered and groundwater would no longer flow into Crooked Creek adjacent to the mine site, nor into adjacent creek beds east of Crooked Creek. Rather, groundwater would flow toward the pit. Also, some surface water in Crooked Creek would seep into the ground and flow to the pit. Mine pit dewatering (at a maximum planned groundwater pumping rate of 2,600 gpm) would create up to 1,600 feet of drawdown in the local groundwater flow system. The areal extent of the cone of depression would be 9,000 acres during operations and 2,000 acres during post-closure. Related reductions in Crooked Creek stream flows are discussed in detail in Section 3.5, Surface Water Hydrology. The Tailings Storage Facility would be lined to mitigate contact water seepage to groundwater, and would be backed up by an underdrain and downgradient seepage recovery system. The Waste Rock Facility would be unlined, and could be a source of contact water that could infiltrate to the groundwater. During operations, this contact water would be captured by pit dewatering; after closure, it would flow into the pit lake. After mine closure, modeling shows that the pit lake would continue to be a destination for groundwater flow, and that Crooked Creek would continue to lose water to the groundwater system flowing to the pit because of ongoing pumping and treating of lake water to keep water levels below surrounding water levels.

The highest intensity groundwater impacts associated with the mine site would occur during the period of active mining. Mitigation recommendations (see Chapter 5) could potentially reduce effects; however, some effects to the groundwater flow system would be permanent.

The transportation facilities would have minor effects on groundwater, limited to potable water supply wells for new port facilities. Groundwater exists in the proposed pipeline corridor within burial depths for the pipeline. However, the potential for disruption of springs in rivers and streams is very low, either because the pipeline does not encounter groundwater (and misses disrupting the flowpath), or because trench plugs are installed to minimize the potential for the pipeline trench to create a preferred pathway and alter the natural flow of groundwater.

Overall, impacts from Alternative 2 on groundwater hydrology, outlined above, are considered minor. However, due to uncertainties within the models used, they could be classed as moderate.

Other Alternatives: The effects of other alternatives on groundwater hydrology would be similar to those of Alternative 2. Differences of note include:

- *Alternative 5A (Dry Stack Tailings)* would exchange dry stack design for the pond design of the Tailings Storage Facility under Alternative 2. Where the Tailings Storage Facility under Alternative 2 would be lined, dry stack tailings under Alternative 5A would be unlined under Option 1, lined under Option 2, and both capped at closure. After 200 years, the quantity of seepage from the unlined dry stack would be similar to the amount of seepage through the liner in Alternative 2. Under Alternative 5A-Option 2, the liner underneath the dry stack would result in seepage rates comparable to Alternative 2 at closure. Under both options in Alternative 5A, seepage flow would be captured by a seepage recovery system comparable to that of Alternative 2. Overall impacts to groundwater are expected to be minor.

3.6.1 AFFECTED ENVIRONMENT

3.6.1.1 APPLICABLE REGULATIONS

Groundwater resources are governed by several applicable regulatory programs. Table 3.6-1 summarizes the federal and State of Alaska regulations affecting groundwater. While drinking water sources are regulated by federal laws and regulations, chiefly the Safe Drinking Water Act, Alaska has received primacy as a result of having adopted regulations that are at least as stringent as federal regulations. Nationally, except for federal reserve water rights, statutes and regulations governing water diversion, water use, and water rights are customarily left to the states. Temporary or long-term permits are required for practically any diversion of water or pumping of groundwater above minimum thresholds as defined by regulations (11 AAC 93.035). Alaska also has in-stream flow water rights regulations designed to protect certain in-stream flow quantities or lake levels for aquatic habitat, recreation, navigation, or water quality. Although these regulations are primarily related to surface water bodies, they are potentially applicable in situations where potential changes to groundwater resources may have impacts on surface waters. Additional state and federal regulations affect groundwater quality and are addressed in Section 3.7, Water Quality.

Table 3.6-1: Federal and State Regulations Affecting Groundwater Quantity

Agency and Regulatory Program	Regulation	Description
Federal		
EPA Sole Source Aquifer Protection	Section 1424(e) of the Safe Drinking Water Act of 1974 (Public Law 93-523, 42 U.S.C. 300 et seq.).	SSA designation is a tool to protect drinking water supplies in areas where few or no alternative sources to the groundwater resource exist and where, if contamination occurred, using an alternative source would be extremely expensive. The designation protects an area's groundwater resource by requiring EPA to review certain proposed projects within the designated area.
Federal and State of Alaska		
ADEC Public Drinking Water Systems and protection areas	18 AAC 80 (and federal 40 CFR Part 141, 40 CFR Part 142, and 40 CFR Part 143**)**	Alaska has primacy on regulating public drinking water systems with many references to federal regulations. Regulations also contain references to Drinking Water Protection areas that have been mapped for many public drinking water systems.
State of Alaska		
ADNR Temporary Water Use Authorization or Water Appropriation	11 AAC 93	Temporary water use authorizations and/or water rights permits and certificates are needed for use of a significant amount of water, including groundwater, as water rights can be issued for both surface and subsurface water. This may apply to the mine and process facility's water use, camp water use, dust control, pipeline construction or testing, ice roads, mine dewatering, dewatering of pipeline trenches, water extraction, treatment, and discharge, and all other water diversions.
ADNR In-stream flow reservations	11 AAC 93.141-147	In-stream flow reservations may be filed with ADNR by interested parties for maintaining stage or discharges in streams or rivers or maintaining minimum levels in lakes.

Notes:

ADEC – Alaska Department of Environmental Conservation
ADNR – Alaska Department of Natural Resources
EPA – Environmental Protection Agency
SSA – Sole Source Aquifer

3.6.1.2 HYDROGEOLOGICAL SETTING AND DATA SOURCES

The proposed project area encompasses seven physiographic sub-provinces spread across Southwest and Southcentral Alaska and the Aleutian Island Chain with diverse hydrogeological settings. These are described in the following subsections for each of the three proposed project components (mine site, transportation facilities, pipeline), along with a summary of available data sources used in the analysis.

3.6.1.2.1 MINE SITE

Groundwater data and data analyses for the proposed mine site are contained in reports by BGC (2011d, h, i, g, 2014f, g, c). Groundwater data for the proposed mine and process facilities area have been collected from 198 monitoring locations, including 135 monitoring and test pumping wells and 63 vibrating wire piezometers. To measure vertical groundwater gradients, 29 nested well or piezometer pairs were installed. To measure hydraulic conductivities of aquifers, 40 tests were performed in non-lithified materials (including 35 slug tests and 5 estimates of hydraulic conductivity from 3 pumping tests; one of which was at a larger scale than the rest) and 931 tests were performed in bedrock in more than 130 boreholes. To measure hydraulic conductivity on a larger scale than near a single borehole, 13 aquifer tests using pumping wells were also conducted (including 12 in bedrock and the one larger scale test in non-lithified materials noted above). Geological information, including information about the distribution of permafrost and the geological formations found in the area, were also collected as part of the groundwater data collection program.

The proposed mine and process facilities would be located in a region of localized discontinuous permafrost where groundwater occurs throughout the area, both in permafrost-free areas and above and beneath permafrost. Groundwater is found in alluvial, colluvial, terrace gravel, and loess deposits as well as in fractured bedrock. Most recharge to groundwater occurs in the non-freezing months from snowmelt, rainfall, or recharge from streams. Local permafrost can impede groundwater recharge or confine groundwater in some areas; however on a basin-wide scale, permafrost is considered too sporadic to substantially impede recharge or discharge. Natural groundwater discharge occurs in most of the main stream and river bottomlands throughout the year. Wintertime surface water flows, for example, are sustained almost entirely by groundwater discharge.

3.6.1.2.2 TRANSPORTATION FACILITIES

The proposed transportation corridor includes the port at Dutch Harbor, the Kuskokwim River lowlands (including a fuel storage and transfer facility at Bethel), a proposed river port facility on the Kuskokwim River, and road corridor from the river port to the proposed mine site. Data on groundwater for the transportation corridor includes: about 130 geotechnical borings at the potential Angyaruaq (Jungjuk) and BTC Port sites and along the proposed road alignments (DMA 2007a, 2007b; RECON 2011a); well log data from Bethel and other river communities (ADNR 2013c); and data from the Alaska Department of Environmental Conservation (ADEC) Public Water System and Contaminated Sites databases (ADEC 2013a, 2013c).

The Kuskokwim River lowlands (including Bethel) contain coarse-grained alluvial deposits that are capable of yielding large quantities of water to wells where permafrost is thin or absent - usually very close to the Kuskokwim River. At Bethel, where over 400 feet of permafrost has been encountered, yields from wells of approximately 400 gallons per minute (gpm) have been obtained from alluvial deposits below permafrost (ADNR 2013c). Most households in the villages along the Kuskokwim River obtain water from wells. Some wells tap relatively shallow and thawed alluvial deposits while others, such as those in Bethel, tap deeper aquifers below permafrost, or aquifers that appear to be between permafrost layers (ADEC 2013c; ADNR 2013c).

Groundwater has also been encountered in several of the test holes drilled along the proposed road alignments from the Angyaruaq (Jungjuk) and BTC port sites to the proposed mine site. In general, the hydrogeologic setting in this area is similar to that described for the proposed mine site, with most groundwater found in unconsolidated alluvial material in drainages and weathered bedrock. Permafrost, mostly in low-lying areas, provides local confinement of groundwater (DMA 2007a, 2007b; RECON 2011a).

3.6.1.2.3 PIPELINE

Subsurface data on groundwater for the proposed pipeline corridor were obtained from over 500 boreholes and 50 test pit sites. Additionally, 15 test holes were drilled at five different river crossings (BGC 2013c; CH2MHill 2011b).

The proposed pipeline route includes the Cook Inlet lowlands on the east, crossing the Alaska Range and interior lowlands and uplands to the proposed mine site. Southeast of the Alaska Range groundwater is mostly found in permafrost-free environments. At the eastern end of the proposed pipeline corridor, groundwater occurs in the Cook Inlet aquifer system, predominantly glacially-related silt, sand, gravel, clay, cobbles, and boulders. Groundwater can occur under confined or unconfined conditions.

In the Alaska Range, groundwater occurs in alluvial, colluvial, and glacial deposits as well as in bedrock. West of the Alaska Range, permafrost is commonly present in the proposed pipeline corridor and groundwater occurs as suprapermafrost groundwater, or is associated with the larger alluvial fans and drainages. Suprapermafrost groundwater is water found seasonally in saturated soils above permafrost.

3.6.1.3 GROUNDWATER OCCURRENCE AND AQUIFER CHARACTERISTICS

3.6.1.3.1 HYDROGEOLOGIC UNITS

Mine Site

Groundwater in the area of the proposed mine site occurs in three main hydrogeologic environments: 1) an alluvial aquifer associated with Crooked Creek; 2) a thin colluvial layer that covers most of the valley side slopes and valley bottoms; and 3) bedrock aquifers where groundwater is also found in fractures, faults, joints, and weathering voids in intruded sedimentary rocks. The alluvial aquifer consists primarily of sand and gravel with varying amounts of silt in the floodplain and adjacent low terraces of Crooked Creek, and is generally less than 30 feet thick. The colluvial deposits are relatively thin (up to about 7 feet thick on ridgetops and valley walls), but are up to 20 feet thick in valley bottoms. A few monitoring wells have also been completed in loess and terrace gravels; however, these are considered to be very minor hydrogeologic units (e.g., BGC 2011d).

In the vicinity of the proposed mine site, bedrock consists of faulted and folded greywacke, shale, and siltstone intruded by felsic and mafic igneous rocks (Section 3.1.2.1.2).

Permafrost is discontinuous in the area (Section 3.2.2.1.2) and generally causes conditions of lower hydraulic conductivity where it occurs. It may function as a local confining unit or as a barrier to infiltration and recharge. Regionally, however, because it is discontinuous and evidence of any major effect on groundwater flow systems is lacking, it is not considered to be a substantial hydrogeologic unit or barrier to flow (e.g., BGC 2011d).

Transportation Facilities

Dutch Harbor

A number of ADEC-designated contaminated sites, related to historical spills from existing tank farms and fuel handling (unrelated to this project), have been documented in the Dutch Harbor area (Sections 3.2.2.2.4 and 3.7.1.2). Local groundwater information available as a result of site characterization and cleanup activities at these sites indicates the presence of groundwater in shallow soils in low-lying areas like near the Delta Western fuel dock at depths of 10 feet or less, and in volcanic bedrock in hilly areas like Rocky Point at depths ranging from 20 feet to over 100 feet (e.g., Stantec 2010).

Kuskokwim River

Along the Kuskokwim River, alluvial deposits contain alternating layers of sand and gravel, silty overbank deposits, or slack water deposits; and can be up to hundreds of feet thick. Shallow groundwater in unconsolidated deposits along the banks flows into and out of the river in response to changing river levels (Section 3.7.2.2.2, Figure 3.7-7). Permafrost is present intermittently in many places in the Kuskokwim River valley, and in some places reaches depths of up to 400 feet. Wells in Bethel tap an alluvial aquifer beneath 400 feet of permafrost. Wells in other communities obtain water from water table aquifers at a depth of approximately 50 feet that lack effective confining layers of silt or frozen material (Dorava 1994).

Angyaruaq (Jungjuk) and Birch Tree Crossing (BTC) Roads and Ports

Groundwater occurs in sand and gravel alluvium in several drainages crossed by the Angyaruaq (Jungjuk) and BTC road alternatives. These include the drainages of Getmuna and Jungjuk creeks on the proposed Alternative 2 mine access road (RECON 2011a); and the Iditarod and Owhat rivers, and drainages of Cobalt, Tyrel, Kaina, and Ones creeks along the proposed BTC Road (DMA 2007a). No groundwater was encountered in boreholes drilled in intervening upland areas and smaller drainages; however, boreholes were drilled for geotechnical data collection and likely not drilled deep enough to encounter groundwater in bedrock. In general, groundwater conditions in bedrock are expected to be similar to those encountered in the mine and facilities area as a result of similar geology and topography. In a number of the larger drainages, groundwater was present in units below relatively thick (5 to 30 feet) sections of permafrost or unfrozen silt.

Discontinuous groundwater was present in less than half of boreholes drilled in a benched area above the Kuskokwim River at the proposed Angyaruaq (Jungjuk) Port site (DMA 2007b). No groundwater was encountered in boreholes drilled up to 27 feet deep through frozen and unfrozen silt at the proposed BTC Port site (DMA 2007a).

Pipeline

Along the proposed pipeline corridor, groundwater is commonly found in alluvial deposits and wetland areas. Alluvial deposits are typically very permeable and saturated with groundwater to within a few feet of the land surface. Locally, these deposits may contain large quantities of groundwater. Figure 3.6-1 shows the distribution of shallow groundwater (within 3 feet of the land surface) along the pipeline route based on borehole and terrain mapping data in SRK (2013b) and BGC (2013c). Depth to groundwater data are also listed by milepost in Appendix F, the Soil and Permafrost Data, and detailed wetlands mapping is provided in Appendix L, Wetlands Pipeline Mapbook.

Approximately 112 miles or 36 percent of the proposed pipeline route is estimated to be underlain by shallow groundwater during summer, or by major wet organic deposits. Additional seasonal occurrences of thin discontinuous shallow groundwater could occur in the active layer in permafrost areas (shown in Figure 2.3-34, Chapter 2, Alternatives); these are indicated as “frozen” in the geotechnical data and not included on Figure 3.6-1.

3.6.1.3.2 GROUNDWATER FLOW SYSTEMS

Mine Site

The upper surface of groundwater at the mine site is generally known as the water table or potentiometric surface. Figure 3.6-2 shows the configuration of the potentiometric surface in the vicinity of the proposed mine and process facilities. This map is termed a potentiometric surface map because most of the water level data used to construct it were obtained from wells that tap deeper portions of the aquifer, rather than the water table surface. A map of the water table would be similar in configuration because (as discussed below) vertical gradients within the groundwater flow system are not large compared to the scale of the map and the overall relief of the potentiometric surface (BGC 2011d).

The potentiometric surface occurs at or near the land surface near creeks and streams and at depths of up to approximately 300 feet below the land surface at ridgetops (BGC 2011d, 2011h). The configuration of the potentiometric surface generally follows the configuration of land surface contours, so in areas near the perimeter of the facilities where data are too sparse to effectively draw contours of the surface (such as in the vicinity of the proposed Snow Gulch reservoir), the approximate shape of the potentiometric surface and groundwater flow directions can be inferred. Fractures in the bedrock aquifer are considered to be fully saturated with groundwater from the water table to depths greater than the depth of the proposed open pit.

Groundwater flows under natural gradients driven by gravity from highlands to lowlands, generally at right angles to the potentiometric surface contours, discharging to the lower reaches of streams. Analysis of stream discharge records from Crooked Creek indicate that the creek generally gains water in the area of the proposed mine site.

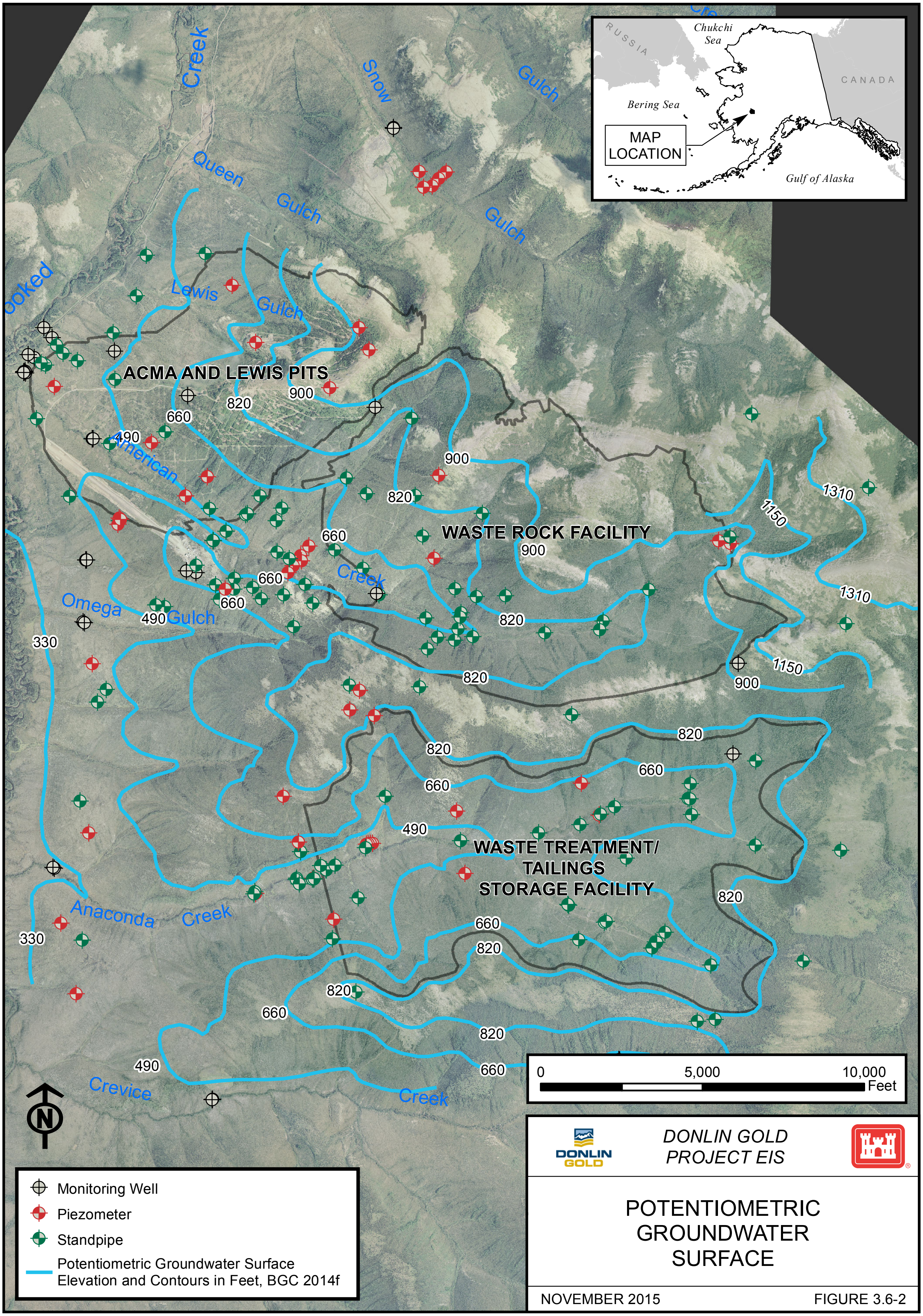
In general, groundwater (while below ground) does not freeze during the winter months, and is capable of providing year-round flows to larger streams and rivers. Groundwater flows from aquifer storage during the winter months (and during summer dry spells) thus causing water levels in the aquifer to fall. Water levels rise and groundwater is replenished during spring snowmelt and also during summer and fall rain events. Groundwater levels generally fluctuate less in lowland settings along creeks at the mine site (up to about 16 feet in any given year) than in upland settings, where levels generally vary by 10 to 66 feet over the course of a year (e.g., BGC 2011d).

DONLIN GOLD PROJECT EIS

SHALLOW GROUNDWATER DISTRIBUTION ALONG PIPELINE ALIGNMENT

NOVEMBER 2015

FIGURE 3.6-1



DONLIN GOLD PROJECT EIS

POTENTIOMETRIC GROUNDWATER SURFACE

NOVEMBER 2015

FIGURE 3.6-2

Groundwater fluctuations and discharge to creeks are driven by groundwater recharge. Recharge at the proposed mine site occurs from rainfall, snowmelt, and to a lesser extent from infiltration from losing reaches of creeks. An estimate of the quantity of groundwater recharge determined from mine site groundwater flow and surface water balance models (Section 3.6.1.3.1) is 5.5 inches per year, or approximately 28 percent of average annual precipitation.

Groundwater recharge was also evaluated by interpretation of data collected for isotopes of hydrogen and oxygen in molecules of groundwater and dissolved helium gas (BGC 2014h). Samples were obtained and analyzed from 18 wells. Ratios of stable isotopes of oxygen and hydrogen were used to conclude that groundwater recharge appears to occur widely throughout the mine site area. Tritium and helium isotopes were used to estimate groundwater ages based on elevated tritium levels that were emplaced into the earth's atmosphere since the early 1950s from thermonuclear testing. The study found that the estimated age of groundwater in the Project Area varies from approximately 21 to 56 years of age (in 2013) and that the conceptual model of older water being found in deeper wells and at places further down the groundwater flow path is substantiated.

Transportation Facilities

On a regional scale, groundwater flow systems in the Kuskokwim river corridor tend to flow to the southwest, generally paralleling surface water flow directions (Dorava 1994). Locally, shallow groundwater in unconsolidated deposits along the banks flows into and out of the river in response to changing river levels (Section 3.7.2.2.2, Figure 3.7-7). The year-round flow of the Kuskokwim River and its major tributaries is attributable to groundwater discharge to the rivers throughout the winter months.

Groundwater flow in Dutch Harbor generally mimics topography. Flow is directed radially away from Rocky Point; northwest towards Delta Western fuel dock and Dutch Harbor, southeast towards Iliuliuk Bay, and southwest towards Ilulaq Lake (Stantec 2010).

Pipeline

Groundwater flow directions along the proposed pipeline corridor in alluvial fans and stream alluvium are likely to be generally parallel to the direction of flow of the associated stream or river. Where alluvial fans exit mountain valleys, it is expected that streams may generally lose water to groundwater systems. Springs and seeps commonly occur at the toe of alluvial fans where groundwater discharges to the surface.

3.6.1.3.3 AQUIFER PARAMETERS: HYDRAULIC CONDUCTIVITY AND SPECIFIC STORAGE

Hydraulic conductivity is a measure of the ease with which water moves through the subsurface; it is used to understand rates of and quantities of groundwater movement. Table 3.6-2 summarizes the results of hydraulic testing to determine estimates of hydraulic conductivity in wells tapping colluvial, alluvial, and bedrock aquifers in the area of the proposed mine site. Some well tests were affected by permafrost and were excluded from the analysis. Not included in Table 3.6-2 were four tests that were also conducted in wells tapping the minor hydrogeologic unit loess and terrace gravels (two tests each), resulting in estimated hydraulic conductivity values of 0.06 and 0.1 feet per day (ft/d) for these units, respectively.

Many of the single-well tests used to construct Table 3.6-2 were conducted in separate, discrete intervals in deep bedrock-aquifer wells, thus providing information on how bedrock aquifer characteristics vary with depth. The testing has shown that the bedrock aquifer is generally less permeable with greater depth.

Table 3.6-2: Summary of Hydraulic Conductivity Estimates from Hydraulic Tests Not Influenced by Permafrost

Aquifer	Upper (less than 330 ft aquifer depth)		Middle (330 to 660 ft aquifer depth)		Lower (greater than 660 ft aquifer depth)	
	Geometric Mean (ft/d)	Range (ft/d)	Geometric Mean (ft/d)	Range (ft/d)	Geometric Mean (ft/d)	Range (ft/d)
Alluvium	11	0.3 to 850	Na	na	na	na
Colluvium	0.06	0.003 to 1	Na	na	na	na
Bedrock	0.3	0.006 to 14	0.03	0.0009-0.9	0.006	0.0003-0.2

Notes:

Includes only tests not affected by permafrost
ft/day = feet per day na = not applicable
Source: BGC 2014c.

Because the edge of the proposed open pit would be less than 1,000 feet from Crooked Creek, detailed aquifer testing adjacent to Crooked Creek was conducted to investigate the relationships between groundwater and surface water in that area (BGC 2014f). The testing found that recharge from Crooked Creek to the alluvial aquifer under pumping conditions was evident. Testing of the bedrock aquifer also found that, while hydraulic conductivities of the bedrock aquifer were much lower than the alluvium, recharge from Crooked Creek to the bedrock aquifer under pumping conditions was also evident. Crooked Creek appeared to be better connected to the alluvial aquifer than to the bedrock aquifer.

In general, fractured rock aquifers are known to have irregular distributions of permeable zones, correlating with the variable distribution of faults and fracture zones of locally higher hydraulic conductivity. This variability is present at the proposed mine site as illustrated by the observed range of hydraulic conductivity measurements at any given depth interval, of approximately three orders of magnitude (Table 3.6-2). Analysis of data at the proposed mine site has not resulted in the identification of any drastically higher or lower hydraulic conductivities associated with faults or water level discontinuities associated with any of the known faults (BGC 2014b). Thus, at the regional or pit-area scale, faults have not been defined as distinct hydrogeologic features. Detailed examination of the available data has also not revealed any significant correlation between bedrock hydraulic conductivity and rock type or formation.

For these reasons, the bedrock aquifer outside of the open pit area is characterized as a single hydrogeologic unit with a representative hydraulic conductivity that decreases with depth (BGC 2014g). Within the pit area, more detailed hydrogeological information is available and hydraulic conductivity variations associated with different rock types was mapped and incorporated into the model. Locally, both within and surrounding the pit area, zones of hydraulic conductivity higher than regional or local averages (by factors of 10 or more) may be present and could influence local groundwater flow fields and groundwater pumping rates from wells.

Specific storage is a measure of the volume of water that an aquifer releases from storage, per volume of aquifer, per unit decline in hydraulic head (or groundwater surface elevation). It is expressed on a unit basis per foot (ft^{-1}) of head change. Specific storage is generally used to understand rates of groundwater withdrawal that can be sustained over the long-term. At the proposed mine site, however, specific storage is used to determine the amount of groundwater that would need to be pumped in order to achieve desired reductions of water levels around the proposed pit and the recovery rate of groundwater levels after pumping stops.

Because slug tests and packer tests are generally unsuitable for determining the specific storage of the aquifers, limited data are available. Estimates determined from aquifer tests at the site indicate that the specific storage of the bedrock aquifer at the proposed mine site ranges from 1×10^{-7} ft^{-1} to 6×10^{-5} ft^{-1}. These volumes of water apply to the "per foot" of water level, or head, change (typically a decline). The alluvial aquifer occurs mostly as an unconfined aquifer and the storage characteristic of the aquifer is known as the specific yield. The geometric mean specific yield of the alluvial aquifer from aquifer testing conducted near Crooked Creek was determined to be 0.03, although the value determined may have been affected by aquifer recharge from Crooked Creek or rainfall or both during the test. No aquifer testing data are available for storage coefficient or specific yield from the colluvium.

3.6.1.4 MINE SITE GROUNDWATER MODEL

A three-dimensional mathematical model of the groundwater flow system in the vicinity of the proposed mine pit and process facilities area has been constructed by BGC (2011d, h, i, 2014g, c) in order to accomplish the following primary goals:

- Better understand pre-mining groundwater flow through the region;
- Plan mine dewatering facilities;
- Estimate the potential effects of the proposed mine on flow in local surface water, in particular Crooked Creek;
- Estimate the effects of proposed tailings storage on groundwater flow;
- Estimate the amount of groundwater that would be collected by the proposed tailings storage facility (TSF) underdrain and seepage collection systems; and
- Estimate the amount of time it would take for the pit lake to fill after mining.

The flow model was developed using MODFLOW-SURFACT, which is based on a groundwater modeling industry-standard three-dimensional finite-difference flow model (MODFLOW) developed by the U.S. Geological Survey (Harbaugh et al. 2000; McDonald and Harbaugh 1988). MODFLOW-SURFACT is a proprietary code developed by HydroGeoLogic, Inc. (1996) that provides advanced features and solver options for MODFLOW.

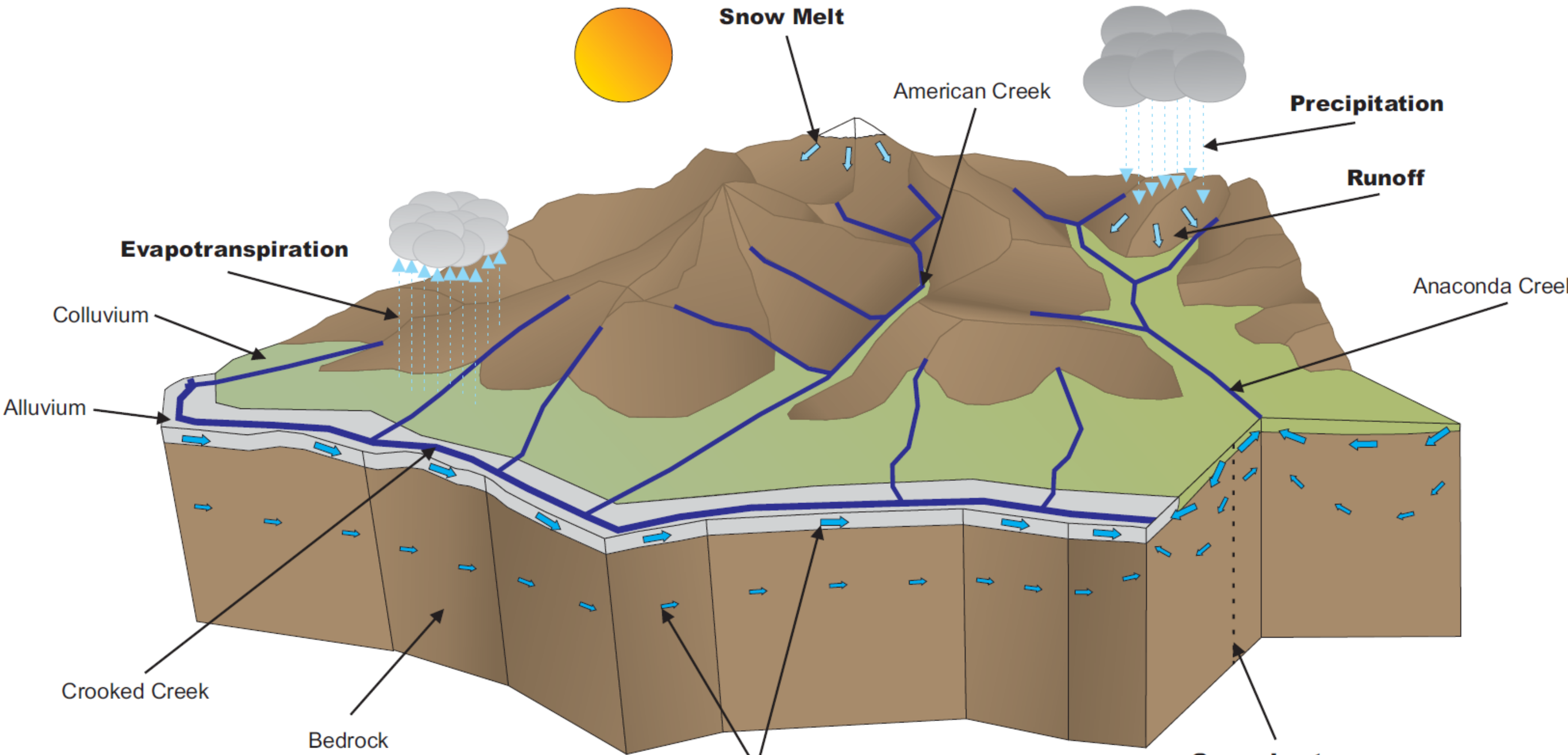
The model employs equations governing groundwater flow, using site-specific estimates of aquifer parameters and boundary conditions derived from field data. The model is capable of simulating groundwater flow for periods of tens of decades or more. Initially, the model is used to simulate natural conditions, followed by simulation of aquifer tests conducted in the area, allowing calibration of the model against real data. The model is then used to simulate various development scenarios. Finally, an important part of the modeling effort is to test the robustness of the model by performing various sensitivity analyses by varying input parameters within reasonable ranges. Groundwater models of this type are widely used to simulate complex groundwater flow systems, provide assessments of potential future conditions, and provide information about the reliability of those assessments.

3.6.1.4.1 MODEL SETUP AND CALIBRATION

The model domain is a roughly 85-square mile area including and surrounding the proposed mine site. The lateral boundaries of the model generally coincide with inferred groundwater divides, which are simulated as no-flow boundaries representing the outer limits of the pre-development groundwater flow system containing the proposed pit. For the most part (as explained further in subsequent sections of this analysis), these boundaries also extend beyond the expected effects of the mine dewatering, indicating that the modeled area is of adequate size. In the southeast portion of the modeled area, the projected drawdown in the groundwater system extends to the model boundary; however, the potential inaccuracies on the overall flow system modeling are considered minor and the use of the 85-square mile area is considered adequate for the purposes of the EIS.

The bottom of the modeled area is 1,500 feet below the deepest planned depth of the proposed mine, which also considered to be an adequate depth of simulation. The model is broken into the following hydrogeologic units (Section 3.6.1.3.1, Figure 3.6-3): alluvium, colluvium, and bedrock, which are further categorized spatially (valleys vs. ridges) and by depth (upper, middle, lower) consistent with the aquifer test results (Table 3.6-2). In the pit area where more detailed hydrogeologic data are available, individual rock units were assigned hydraulic conductivity and storage properties. The model subdivides the flow domain through the hydrogeologic units into 347 columns, 222 rows, and 9 layers, resulting in approximately 693,000 blocks. Some of the blocks around the periphery were deactivated to match flow system boundaries.

The model uses field measurements and field-based estimates for determining initial input parameters for the following: hydraulic conductivity of earth materials; precipitation; evapotranspiration; sublimation/evaporation; runoff; groundwater recharge; stream depths and stages; and well-pumping rates (during aquifer tests). The model output consists of simulated values of hydraulic head throughout the model domain, and quantities of water discharging to streams from groundwater or being recharged to groundwater from streams. These model outputs are then compared to field measurements of the potentiometric surface, seasonal groundwater level trends, aquifer tests, and streamflow. Model input parameters are then changed (calibrated) until a satisfactory fit with field measurements is obtained. Sensitivity analyses were then performed to determine the sensitivity of the model results to reasonable variations in input parameters.



Note: Conceptual diagram only. Drawing not to scale.

Data Sources: BGC 2014g

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CONCEPTUAL HYDROGEOLOGIC MODEL

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FIGURE 3.6-3

Fracture Flow Analysis

The model treats the aquifer domain as continuous porous media even though, in reality, for the bedrock portions of the model, groundwater flows through discrete individual fractures with variable spacing, orientation, and connectivity. The variability of the fracture system is evident in the variable hydraulic conductivity values (heterogeneity) determined from wells tapping the bedrock aquifer during the field testing program. While evidence of large individual fractures that distort the flow field or dominate flow are lacking, they may be present and undetected and may influence the accuracy of model projections. In order to further evaluate this potential phenomenon, sensitivity analyses were performed to examine the potential effects of fractures on groundwater flow.

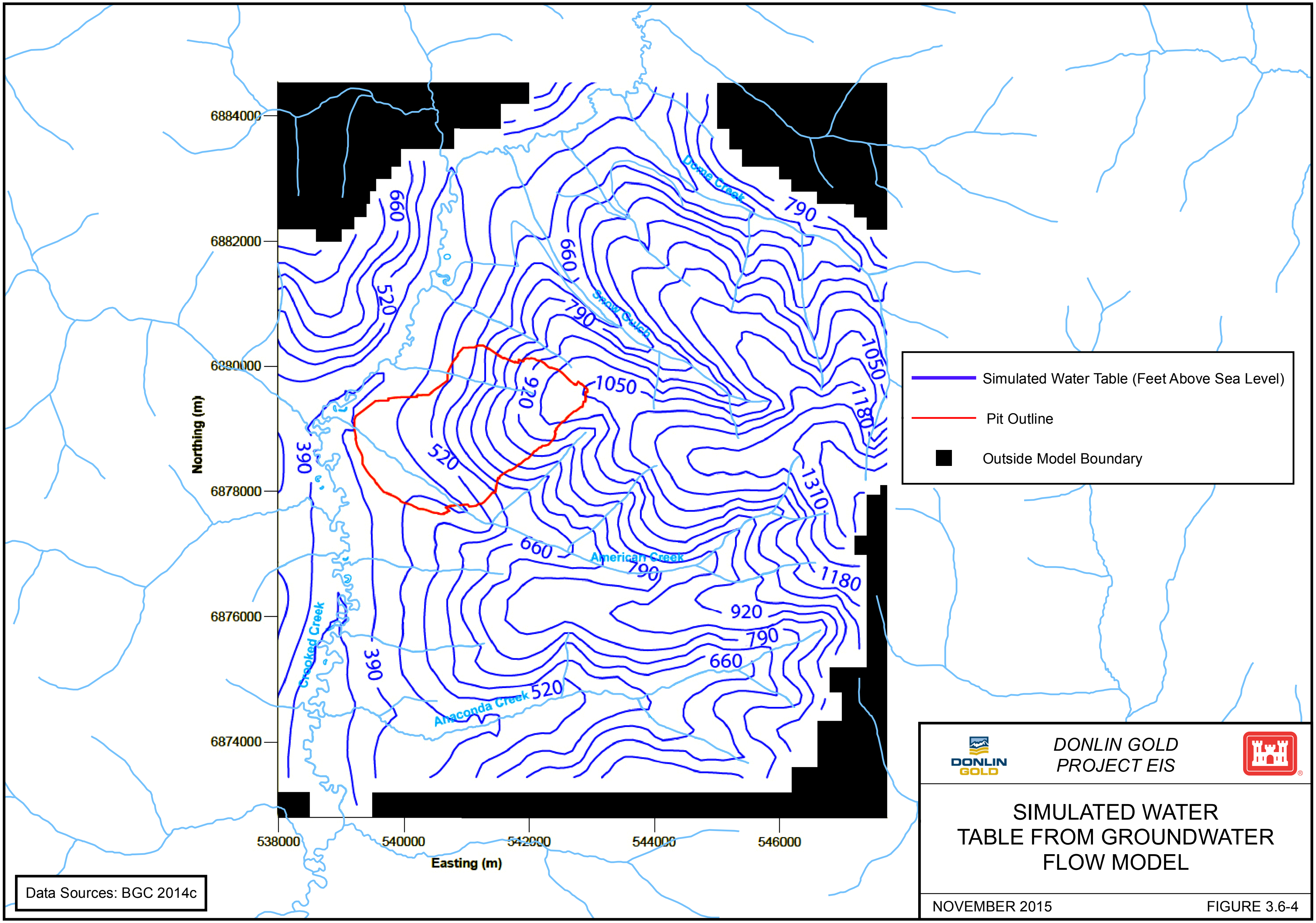
Simulated Potentiometric Surface and Comparison to Field Data

Figure 3.6-4 shows the model-generated potentiometric surface in the vicinity of the proposed mine site. A qualitative comparison to the potentiometric surface map based on field data for the drainages of American and Anaconda creeks (Figure 3.6-2) shows broad similarity with modeled peak water levels under the ridges and Crooked Creek serving as a discharge area from the model flow system. Quantitatively, Figure 3.6-5 shows a comparison of model-generated head values (groundwater elevation) with field-measured head values in wells on a point-by-point basis. The goodness-of-fit of a model such as this with field data is commonly evaluated by calculation of the root mean square (RMS) error (Anderson and Woessner 2002). When normalized by dividing by the total head drop across the flow field, the normalized RMS, or NRMS, is calculated. This number should be "small," i.e., generally less than 10 percent (BLM 2008c). In this case, the NRMS is 5.9 percent, which is considered, in the context of the groundwater modeling industry as a whole, to be an acceptable match between the model results and field data).

The model was also used to simulate seasonal water-level trends at 26 wells where sufficient data were available for comparison. The model divides each simulated year into two time steps, winter (November to April) and summer (May to October). Simulations of summer conditions included groundwater recharge at a uniform rate of 5.5 inches per year, and simulations of winter conditions were conducted with recharge set equal to zero. While the plots show overall groundwater elevation offsets ranging from 0 to 150 feet between the observed and simulated values (results which are captured by the NRMS analysis described above), examination of the seasonal fluctuation patterns generally showed favorable comparability for the period of record. Where actual seasonal fluctuations are small (less than about 5 feet, which generally occurs in lower elevation wells), the modeled results show little to no seasonal fluctuation. Where actual seasonal fluctuations are more pronounced (e.g., on the order of tens of feet, usually in higher elevation wells), the simulated fluctuations are generally within the same order of magnitude (BGC 2011i).

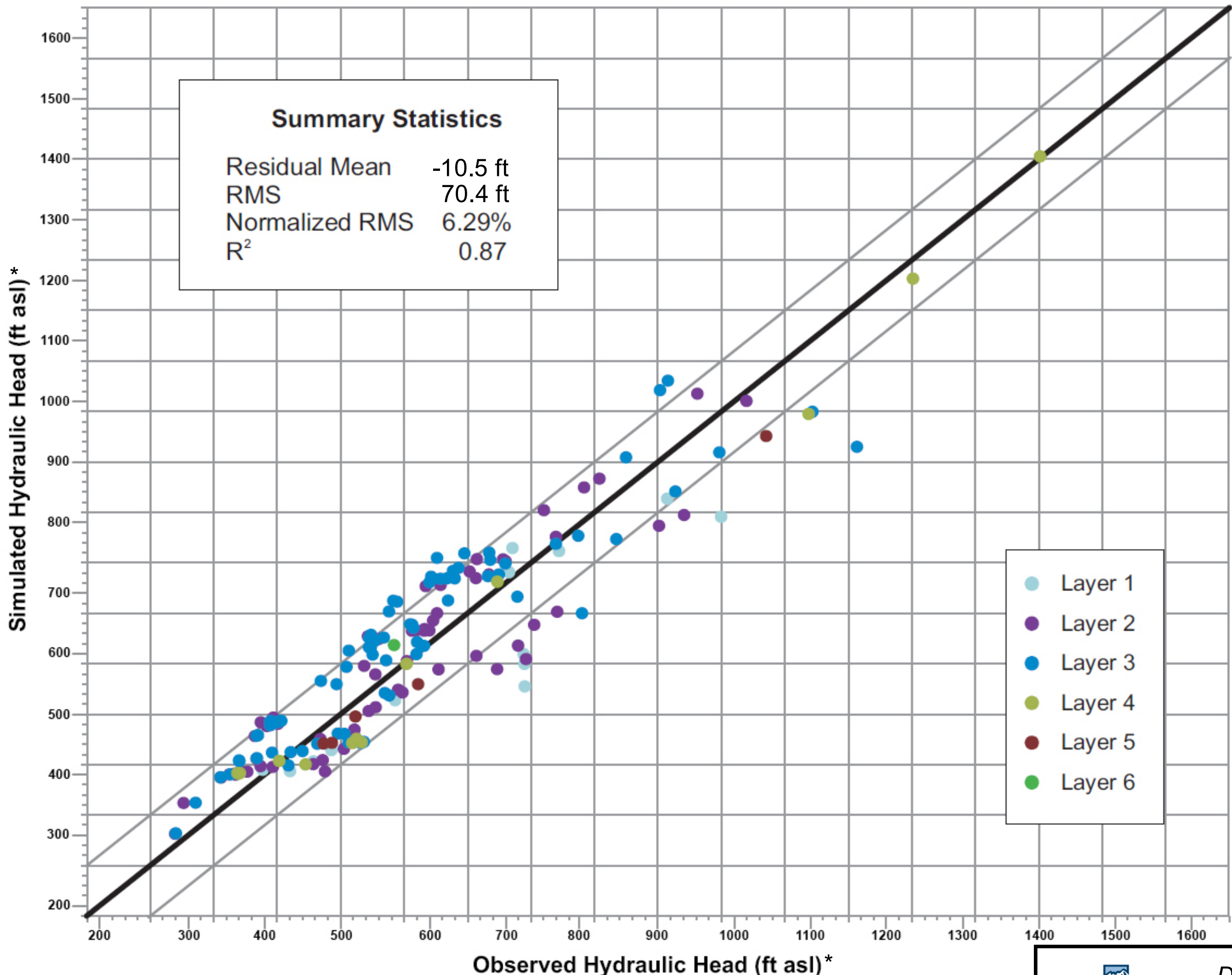
Simulation of Baseflow to Creeks

A comparison of groundwater model-predicted streamflow at five streams with summertime gaged streamflow measurements yielded a NRMS value of 3.3 percent.



SIMULATED WATER TABLE FROM GROUNDWATER FLOW MODEL

FIGURE 3.6-4



DONLIN GOLD

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RESULTS OF MODEL CALIBRATION: SIMULATED VS. OBSERVED MEAN ANNUAL HYDRAULIC HEAD

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FIGURE 3.6-5

Data Sources: BGC 2014c

* Feet Above Sea Level

Simulation of Aquifer Tests and Stream Leakage

Comparison of simulated and measured drawdowns from aquifer tests show variable-quality matches. Some matches are reasonably close; however other matches are not close. This is likely attributable to several factors including the scale of the model grid versus the scale of a well bore and aquifer heterogeneity.

Summary of Model Calibration and Simulation of Future Conditions

The results of the model calibration show that the match between model output and field observations is well within accepted groundwater modeling industry standards, indicating that the numerical model provides a reasonable representation at the project scale of the existing physical hydrogeologic system at the proposed mine site. It was also observed that there is a high degree of heterogeneity with respect to the bedrock hydraulic conductivity at the scale of the aquifer testing.

As is common with models of this type, however, the model is used to simulate conditions (such as dewatering the proposed mine pit) that do not currently exist (Anderson and Woessner 2002). The amount and uncertainty of inaccuracies of these simulations are difficult to gauge. Therefore, sensitivity analysis simulations of mine pit dewatering are used to assess model uncertainty and robustness. These assessments are subsequently used to justify possible mitigation conditions such as additional data collection and periodic model revision as dewatering of the pit progresses. These concepts are further developed in Sections 3.6.2.2.1, 3.6.2.2.6, and Chapter 5, Impact Avoidance, Minimization, and Mitigation.

3.6.1.5 GROUNDWATER USE

3.6.1.5.1 MINE SITE AND PIPELINE

Available ADEC (2013c) and ADNR (2013c) records show that existing use of groundwater for water supply occurs only near each end of the proposed pipeline. In the Beluga area, there are a number of public water system wells located within approximately 1 mile of the diesel pipeline alternative alignment, and several of these may be located within 500 feet of the alignment (e.g., at the Beluga Power Plant). Most residential and commercial users of water appear to have their own wells in this area.

Between Beluga and the proposed mine site, there are no known wells within the proposed pipeline corridor, although there may be groundwater sources (wells or springs) that are in use associated with residences or camps. In many areas near streams, groundwater is shallow enough to be accessed with small-diameter driven point wells that would be unlikely to be registered in public databases.

Two wells are reported to serve the existing Donlin Camp, a main well and a backup well, located at the east end of the current airstrip. A community water supply well is located in the village of Crooked Creek about 10 miles downstream of the proposed mine site and ½-mile southwest of the confluence with the Kuskokwim River. Subsurface water rights are held here by Crooked Creek Traditional Council. The drinking water source protection area identified by ADEC (2013c) for these groundwater supplies extends across the mouth of Crooked Creek.

3.6.1.5.2 TRANSPORTATION FACILITIES

Nine villages are located between Bethel and Crooked Creek along the Kuskokwim River and adjacent sloughs (Kwethluk, Akiachak, Akiak, Tuluksak, Lower Kalskag, Upper Kalskag, Aniak, Chuathbaluk, and Napaimute). Each village except Napaimute has records of one or more wells drilled for water supply. While most well records are for public water systems, there are also some records of privately owned wells. Bethel has the most numerous wells, with approximately 17 known public water systems served by wells, although a few are inactive. Wells have been in use in Bethel for several decades, so there is also the possibility that there are some formerly-used wells that are not part of current public water systems. There are records of a few other wells in Bethel that may be privately owned and used for residential or other purposes (ADEC 2013c; ADNR 2013c).

3.6.1.6 CLIMATE CHANGE

Climate change is affecting resources in the EIS Analysis area and trends associated with climate change are projected to continue into the future. Section 3.26.3 discusses climate change trends and impacts to key resources in the physical environment including atmosphere, water resources, and permafrost. Current and future effects to subsurface hydrology are tied to changes in water resources (discussed in Section 3.26.3.2).

3.6.2 ENVIRONMENTAL CONSEQUENCES

Criteria for determining the groundwater hydrology impacts are based on intensity, duration, extent, and context, as shown in Table 3.6-3. As described in Section 3.6.1.1, groundwater diversion and use is primarily governed by State of Alaska statutes and regulations, which are considered in determining the context of groundwater (common, important or unique) in this section.

Table 3.6-3: Impact Criteria used for Groundwater Resources

Type of Effect	Impact Component	Effects Summary		
Changes to Water Quantity	Magnitude or Intensity	**Low**: Groundwater flow systems are maintained. Changes in water quantity within historic seasonal or minimal variation.	**Medium**: Changes in groundwater flow system, with alterations in flow quantity and location. Effects exceed historic seasonal variations, but nearby uses and environments are maintained.	**High**: Substantial flow diversions and changes in flow systems affecting nearby uses or environments.
	Duration	**Temporary**: Resource would be reduced infrequently but not longer than the span of the project construction and would be expected to return to pre-activity levels at the completion of the activity.	**Long-term**: Resource quantities would be changed throughout the life of the mine for up to 100 years after the end of construction; however, they would return to pre-activity levels sometime during that period.	**Permanent**: Chronic effects; resource would not be anticipated to return to previous conditions or would take longer than 100 years to do so.

Table 3.6-3: Impact Criteria used for Groundwater Resources

Type of Effect	Impact Component	Effects Summary		
Changes to Water Quantity (cont'd)	Geographic Extent	**Local:** Impacts limited geographically; discrete portions of the Project Area affected. Hydraulically connected waters beyond the Project Area are not affected.	**Regional:** Affects hydraulically connected waters beyond a local area, potentially throughout the EIS Analysis Area.	**Extended:** Affects hydraulically connected waters beyond the region or EIS Analysis Area.
	Context	**Common:** Affects usual or ordinary resources; not depleted or protected by legislation.	**Important:** Affects depleted or shared resources within the locality or region or resources protected by legislation, or resource hazards governed by regulation.	**Unique:** Affects unique resources or resources protected by legislation.

Groundwater is an abundant resource throughout most areas of Alaska, and is not currently considered a depleted resource in the Project Area. Groundwater diversions proposed as part of the Donlin Gold Project, however, are governed by state regulations for even small amounts, at least partly because the diversions could potentially have effects on other resources, notably biological resources associated with Crook Creek. Groundwater is considered an important (but not unique) resource when it applies to a specific purpose such as recharging fish habitat or providing a drinking water supply, however where such values are absent, the context of the groundwater resource is characterized as common.

In evaluating negative and positive impacts to groundwater resources, relevant factors for this project include:

- Impacts to groundwaters that have an identifiable beneficial use such as drinking water or are important for maintaining fish habitat;
- The size of area impacted; for example, potable water well impacts would be more localized than pit dewatering; and
- The degree to which changes are long-term or reversible, such as the recovery of groundwater levels after pumping wells cease (long-term but reversible) versus changes in directions of groundwater flow systems created by permanent lowering of pit lake water levels.

3.6.2.1 ALTERNATIVE 1 - NO ACTION

Under the No Action Alternative, the project would not be undertaken; there would be no mine site development, transportation facilities, or natural gas pipeline. Consequently, groundwater systems would remain in their natural state (where not already being utilized by other parties), and there would be no direct or indirect impacts on groundwater from implementation of the No Action Alternative.

3.6.2.2 ALTERNATIVE 2 – DONLIN GOLD'S PROPOSED ACTION

3.6.2.2.1 MINE SITE

<u>Construction</u>

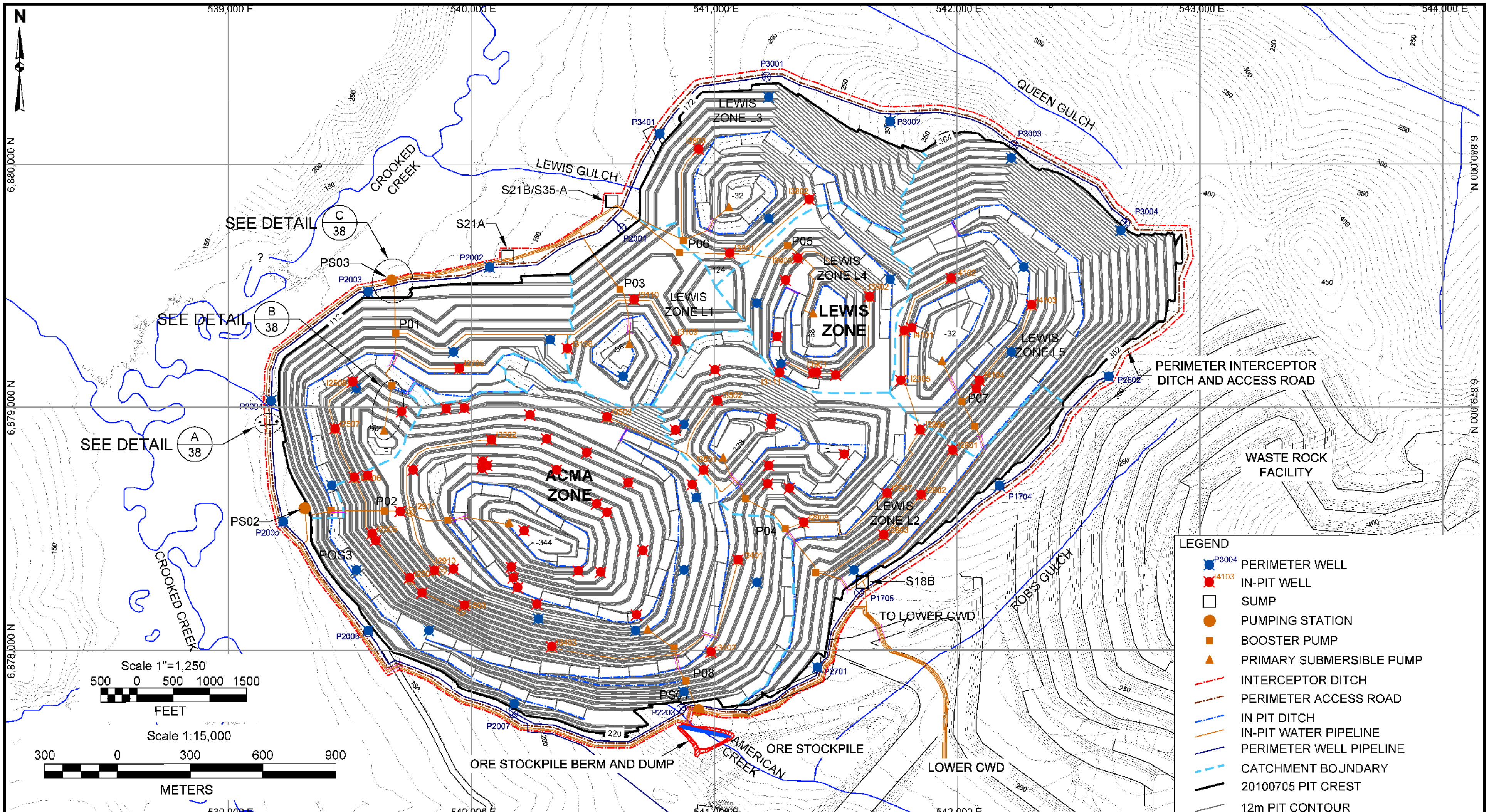
Pit Dewatering

Construction of the open pit requires lowering the water table in and surrounding the area of the proposed pit in order to establish stable pit walls and dry working conditions in the pit bottom. The water table is lowered by means of dewatering wells around the pit perimeter, wells in the pit bottom, and horizontal drains in the pit walls (see Figure 3.6-6). The resulting depression of the water table is known as a cone of depression. Pit dewatering would be initiated during the construction phase. Initially, approximately 17 wells would be drilled around the perimeter of the initial excavations and pumped at an average total rate of about 1,700 gpm when the dewatering system is turned on approximately two years prior to operations. Based on average precipitation conditions, it is estimated that approximately 4,600 acre-feet of groundwater would be pumped out during the 2-year construction phase (SRK 2012b). This would result in a cone of depression that deepens and widens as excavation progresses and would last as long as the dewatering system is operated during construction and operation of the mine (see text and figures in the Operations and Maintenance section below) (BGC 2011d, 2014c).

The creation of a cone of depression around the pit changes the groundwater flow system by causing groundwater to flow towards the open pit from Crooked Creek. Groundwater would no longer discharge to the east bank of Crooked Creek in the vicinity of the pit and some of the water flowing in Crooked Creek would leak into the groundwater system and ultimately flow into the pit dewatering system. This is further described in the Operations and Maintenance section below.

Water Use

Fresh water for the construction camp and ancillary water uses such as dust control, truck washing, and fire protection would be obtained from eight water wells that would be drilled between Omega Creek and an unnamed creek to the south (see Figure 2.3-7, Chapter 2, Alternatives). The wells would be drilled approximately 3,000 to 4,000 feet from Crooked Creek. Total flow from the wells would be an average of approximately 156 gallons per minute (BGC 2014c). The wells would tap the bedrock aquifer. A temporary, localized cone of depression caused by this pumping would develop around the well field, lasting only as long as the construction camp is operational (about 3 years). This cone of depression, which would be very small compared to that caused by dewatering of the pit, would be considered a low magnitude impact. Water rights for this proposed use of water have been applied for in the amount of 201 acre-feet / yr (125 gpm on a continuous basis).



Data Source: BGC 2014c

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OPEN PIT DEWATERING SYSTEM

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FIGURE 3.6-6

NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "DONLIN GOLD PROJECT NUMERICAL HYDROGEOLOGIC MODEL," AND DATED JULY 2014.
3. BASE TOPOGRAPHIC DATA BASED ON LIDAR DEM PROVIDED BY BARRICK GOLD CORP. DATED SEPTEMBER 1, 2004. CONTOUR INTERVAL IS 10 m.
4. FSU II PIT DESIGN (DC_MY10_DESIGN(JUL 5TH 10).dxf) PROVIDED BY BARRICK GOLD CORP. JULY 5, 2010.
5. PROJECTION IS NAD83 UTM ZONE 4N.
6. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING SHALL NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES OR LOSS ARISING IN ANY WAY FROM ANY USE OR MODIFICATION OF THIS DOCUMENT NOT AUTHORIZED BY BGC. ANY USE OF OR RELIANCE UPON THIS DOCUMENT OR ITS CONTENT BY THIRD PARTIES SHALL BE AT SUCH THIRD PARTIES' SOLE RISK.

Contact Water

Contact water would be likely to enter the groundwater system as seepage from the WRF beneath the construction-stage footprint of the WRF, the lower contact water pond, or as seepage through the lower contact water dam (CWD). This water would be captured by the ACMA pit dewatering system or by a proposed ore stockpile berm designed to minimize runoff into the ACMA pit. The impacts are expected to be local in extent and low magnitude, since the water will be captured and used in the mining process. Some of the water pumped by the dewatering system would also be treated and discharged. After closure, the pit lake management system will ensure that the groundwater flow system continues to deliver this contact water to the pit lake for eventual treatment and discharge (see additional discussion of the pit dewatering system in Chapter 2). Thus the impacts will be long-term, but local, and low in magnitude.

Snow Gulch Reservoir

Construction of the Snow Gulch Reservoir would result in impoundment of surface waters and infiltration of surface water into the adjacent groundwater aquifer. The proposed dam height of 151 feet indicates that ground water levels immediately adjacent to the reservoir would likely rise by a similar amount. Groundwater would also be expected to flow through the aquifer under and around the dam as a result of the steepened groundwater gradients, however the amount of flow is expected to be much less than the normal surface water flow in Snow Gulch as a result of the relatively low hydraulic conductivity of aquifer materials. The extent of the higher water table adjacent to the reservoir is not expected to extend any further than the Snow Gulch watershed boundaries as a result of the relatively low hydraulic conductivity of the aquifer and the relatively steep sides of the gulch above the reservoir.

<u>Operations and Maintenance</u>

Pit Dewatering

As development of the pit proceeds, additional in-pit wells and horizontal drains would be installed to yield a peak total flow of 2,600 gpm in Year 12. The proposed mine pit would require the eventual use of 35 vertical wells around the perimeter of the pit and approximately 80 wells in the interior of the pit, as well as approximately 1,790 horizontal drains progressively drilled into the pit walls, to dewater and reduce pore pressures in the bedrock aquifer. Based on average precipitation conditions, it is estimated that approximately 56,100 acre-feet of groundwater would be pumped out during the operations period, for a total of 60,700 acre-feet over the life of the mine (BGC 2015f; SRK 2012b). The effects of pit dewatering would extend to the location of the construction camp wells, which are also expected to be pumped at 30 gpm during the operational period for potable water for the plant. Pit dewatering would occur until the pit reaches its maximum depth of approximately 1,850 feet (below the high wall of the pit on the northeast side). As described in Section 3.6.1.4, a three-dimensional groundwater flow model was developed to plan and evaluate the proposed pit dewatering, changes to the groundwater flow system, induced stream leakage into the groundwater system, and effects of the tailings and waste rock storage facilities. The results of the model analysis (BGC 2014g, c) are incorporated into the discussion below.

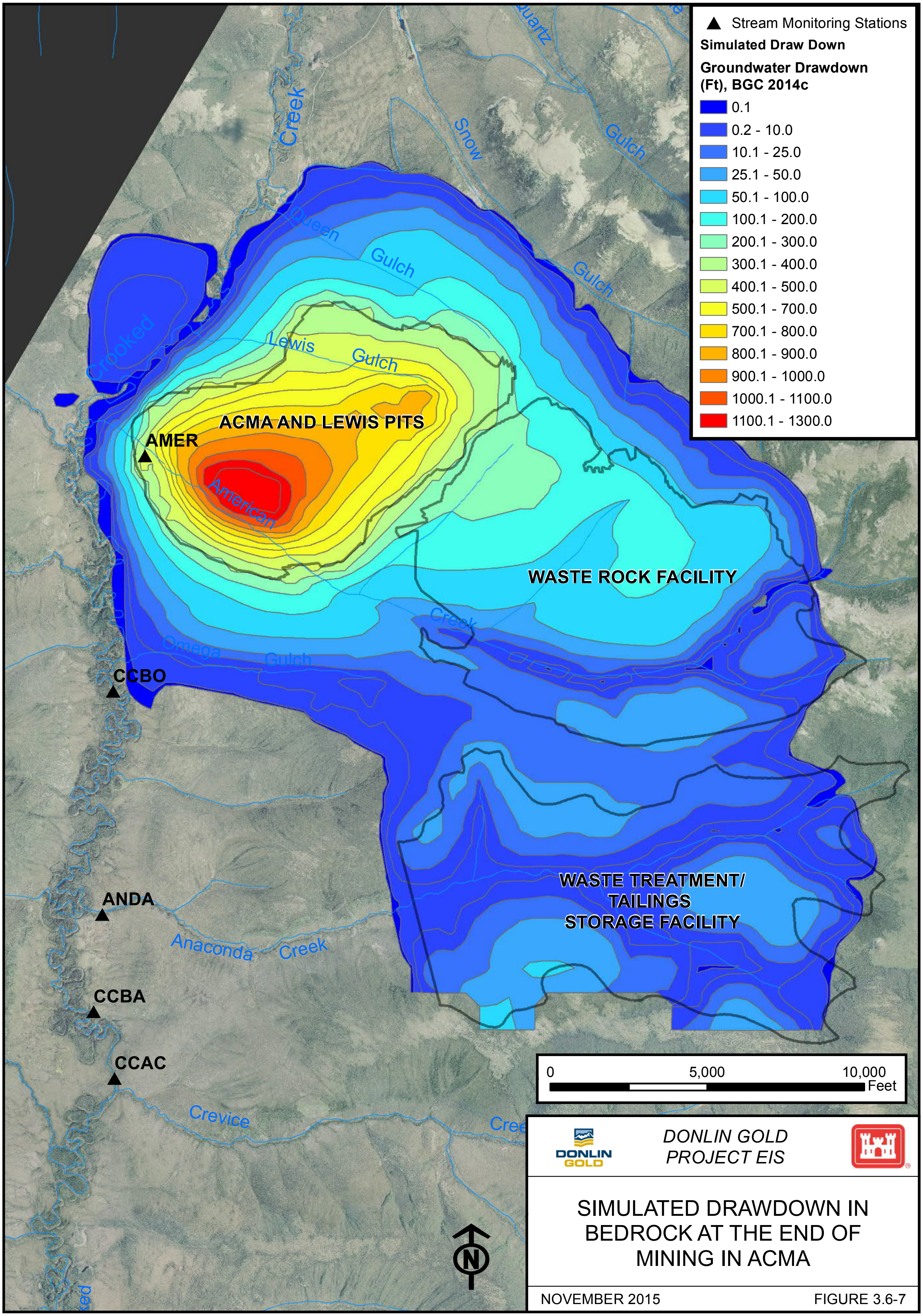
Groundwater obtained from the pit dewatering system would be used for mill process water, for returning water to Crooked Creek via a proposed Advanced Water Treatment (AWT) plant, and for dust control, fire training, and suppression. Water rights have been applied for in the amount of 5,645 acre-feet / year (3,500 gpm on a continuous basis).

The cone of depression represents the level of the water table in the vicinity of the proposed pit; it expands with time as groundwater is pumped and the pit expands and deepens. The maximum drawdown from the pre-mining water table at the ACMA zone (on the southwest side of the pit) is expected to be approximately 1,600 feet, occurring before the end of mining in the ACMA pit. A cone of depression would form around the proposed open pit (see Figure 3.6-7 and Figure 3.6-8). The lowered water table would also extend southeastward to the areas of the proposed WRF and TSF as a result of reduced groundwater recharge under those areas. One of the effects of the cone of depression would be to direct groundwater flow radially towards the pit from all directions, rather than towards the lower reaches of local creeks and Crooked Creek as occurs under natural conditions. The cone of depression would also induce flow of water from creeks into the groundwater system. The tight concentration of groundwater contours between the mine pit and Crooked Creek and the presence of drawdown in bedrock on the west side of Crooked Creek (Figure 3.6-7) is the result of continuous leakage of water from Crooked Creek into the groundwater flow system towards the proposed pit and the resistance to groundwater flow caused by the relatively low hydraulic conductivity of the bedrock aquifer between the creek and the pit.

The pit dewatering system is designed with numerous redundancies, including multiple wells and in-pit pumps. A complete failure of this system is considered extremely unlikely, in that it would threaten the safety of mine personnel, the stability of pit walls, and continued operation of the mine. A failure of a portion of the system, however, could result in the slow recovery of groundwater levels in the area of the failure until repairs were implemented. The effects of such a failure on the spatial extent of any contaminated groundwater in the vicinity of the pit would be minimal because it would take months to years for there to be any substantial changes in the groundwater flow systems from such a failure.

Flows in the lower reaches of local creeks and Crooked Creek adjacent to the proposed pit would be reduced during mine operations compared to pre-mining conditions because of a reduction of groundwater discharge to streams, induced leakage from streams to the pit dewatering system, and the capture of American and Anaconda creeks for use in mining operations. Additional discussion of these surface water effects are contained in Section 3.5, Surface Water Hydrology.

The effects of pit dewatering on Crooked Creek are largest in the winter when streamflow is most supported by groundwater as baseflow. The base case groundwater model that simulates the mine scenario (see Section 3.6.1.4) predicts that some flow of Crooked Creek would be diverted to the pit dewatering system through stream leakage and groundwater flow. Sensitivity analysis simulations (see discussion below in this section) suggest that prediction of the amount of streamflow depletion is difficult.



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SIMULATED DRAWDOWN IN BEDROCK AT THE END OF MINING IN ACMA

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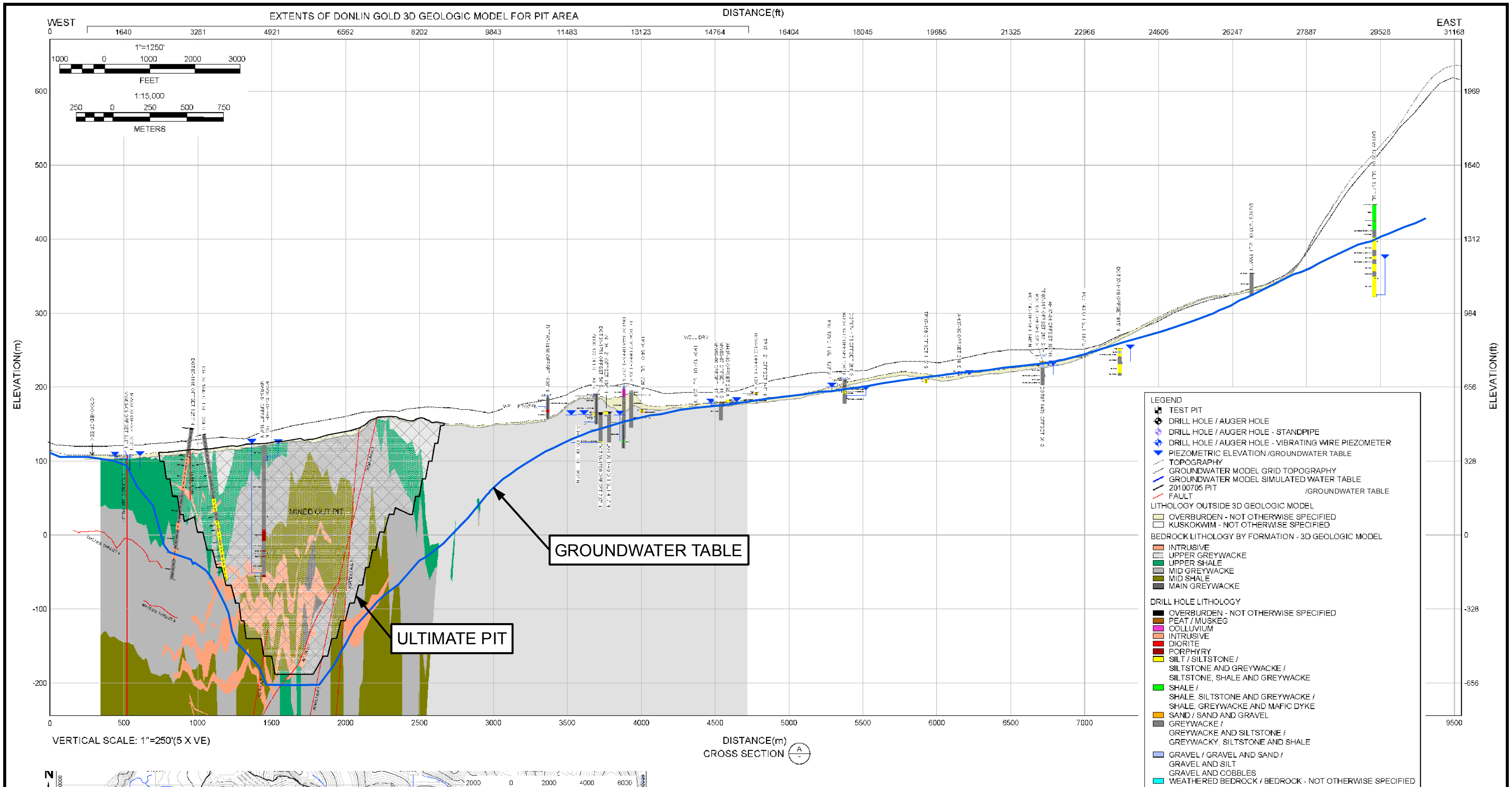
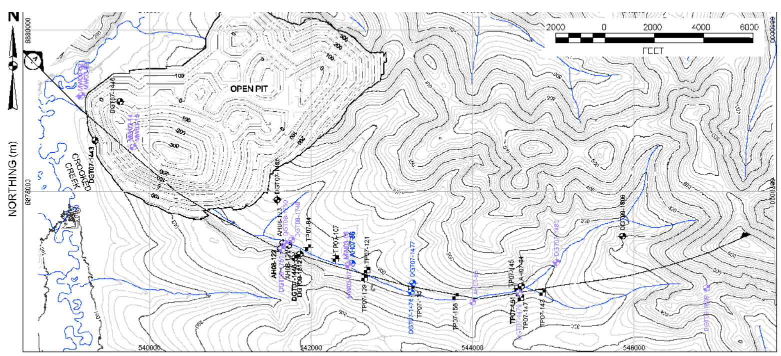
FIGURE 3.6-7





Data Sources: BGC 2014c

DONLIN GOLD

DONLIN GOLD PROJECT EIS

CROSS-SECTION SHOWING PROPOSED CONE OF DEPRESSION AROUND ACMA

NOVEMBER 2015

FIGURE 3.6-8

A streamflow reduction analysis was performed that uses a combination of the groundwater flow model and a surface water flow model (called the Water Balance Model or WBM) in an integrated modeling approach (BGC 2015c, h). The integrated approach is considered superior to analyses of stream depletion using the groundwater flow model alone, because it is capable of incorporating additional data, smaller time steps, and more realistic scenarios for analysis. The integrated model addresses seasonal streamflow reduction under normal flow (50 percent likelihood), low flow (10-percent likelihood), and both mid-range and high aquifer hydraulic conductivity scenarios for different stages of mine development. These results are explained more fully in Section 3.5, Surface Water Hydrology; however, key findings are summarized here that are pertinent to the groundwater system, which during base flow conditions is the dominant driver of streamflow changes.

Stream losses to groundwater are expected to occur mostly along a 2- to 3-mile long stretch of Crooked Creek and its tributaries located in closest proximity to the pit. The reduction in streamflow resulting from losses to groundwater is most pronounced during the winter months (December through March) because streamflow is naturally lower during those months and because most streamflow during those months under natural conditions is the result of groundwater discharge to the creeks. Also, the water treatment plant, which would return water to Crooked Creek during the summer months, would not normally be operating during the winter.

Under low flow conditions (10 percent probability), Crooked Creek streamflow at American Creek is expected to be reduced by almost one-third during the months of December through March (28 percent through 33 percent) at Year 20 of mine development, which is near the maximum development of groundwater impacts on streamflow (BGC 2015h). During average flow conditions, for comparison, flow reductions are expected to range from 19 to 23 percent during those months. Annual average streamflow reduction is expected to be 17 percent under average flow conditions and 22 percent under low flow conditions.

Streamflow reductions were also evaluated considering a scenario with high hydraulic conductivity (high K) values in the groundwater flow model as described in more detail below. Under this scenario at American Creek, 46 to 67 percent of wintertime flow in Crooked Creek is expected to be lost under normal (50 percentile) flow conditions, while 69 to 100 percent of the wintertime streamflow is expected to be lost under low-flow conditions at Year 20. Average annual streamflow reduction of Crooked Creek at American Creek under the high hydraulic conductivity scenarios is expected to be 31 percent under average conditions and 46 percent under low flow conditions.

During closure, impacts to streamflows are expected to gradually become reduced as the pit lake fills and the groundwater gradients driving seepage out of Crooked Creek weaken. After the pit lake reaches its full managed level, streamflow reductions in Crooked Creek caused by loss to groundwater or reduction in groundwater inflow to streams are expected to be very low - generally a few percent or lower.

Because of the effect that these flow reductions have on aquatic habitat or other streamflow-related resources (see further discussion in Section 3.13, Fish and Aquatic Resources), the magnitude of impacts could range from low to medium, at least seasonally or under conditions of higher than expected aquifer hydraulic conductivity or unusually low natural streamflow.

Maximum impacts would be considered to be long-term in duration. Potential impacts would be considered local, as reductions in flows would occur across about a 2- to 3-mile stretch around the mine site and would extend some distance downstream, however no further than the mouth of Crooked Creek located about 13 miles to the south. Downstream from the mine site, additional groundwater and surface water influx to Crooked Creek would tend to mitigate the loss of water near the mine site. For example, downstream of Crevice Creek, annual average flow reductions from pit dewatering would be in the range of 13 to 25 percent under average, low flow and high hydraulic conductivity scenarios, although peak monthly flow reduction would still be up to 85 percent under the low flow and high hydraulic conductivity scenario (Table 3.5-26 in Section 3.5, Surface Water Hydrology). The context of the water resource lost from Crooked Creek is considered to be important.

Tributaries on the east side of Crooked Creek (e.g., Queen's Gulch) would also be depleted of water to varying degrees depending on their proximity to the proposed open pit and use for other major mine facilities. However, tributaries on the west side of Crooked Creek are not expected to be affected because the cone of depression would not extend very far west of Crooked Creek.

Model Robustness and Accuracy

Evaluation of the results of the base case groundwater flow model includes an assessment of the model's robustness and accuracy because the reliability of the modeling results can influence management decision-making and the applicability of concepts such as adaptive management. Robustness of a groundwater model is a characteristic that describes the variability of the model's outputs based on reasonable or plausible variations in model inputs.

As previously described, many of the input parameters to the groundwater model contain uncertainty. The resulting calibrated model, while meeting acceptable calibration criteria, is a non-unique solution to the groundwater flow equations. Other combinations of model parameters could provide comparable calibrations. Simulations of future conditions such as pit dewatering using different sets of input parameters could result in considerably different results. This effect is commonly addressed in groundwater modeling studies by performing a sensitivity analysis on the base case model (Anderson and Woessner 2002). The base case model is the calibrated transient groundwater flow model that simulates open pit dewatering as described in prior sections. During a sensitivity analysis, selected parameters are varied within plausible ranges and the effects on the models predictive results are compared. Generally, a robust model is one in which the results of such simulations do not vary significantly from the base case. If model results are found to vary significantly from the base case, then limitations on the potential accuracy and reliability of simulation results should be reported, particularly with respect to their use in making management decisions (Anderson and Woessner 2002).

A total of 11 sensitivity analysis scenarios were performed (BGC 2014c) and most of them provided relatively minor variations in model output, indicating that the model, in general, is relatively robust. One scenario was concluded to not represent a plausible variation in input parameters. Two other sensitivity analysis scenarios, however, resulted in significant variation from base case modeling results. First, the hydraulic conductivity of the bedrock aquifer was increased by a factor of five while all other model parameters remained unchanged. This variation is considered a plausible amount that hydraulic conductivity could differ from the base case (and is sufficiently different that significant differences in model output might occur) and is well within the observed range of field measurements for this parameter (e.g., BGC

2014f) (see Section 3.6.1.3.3). While this is not a probable scenario because the model is not as well calibrated under this scenario, it shows that the maximum hypothetical percent reduction in flow of Crooked Creek at Station CCBO during wintertime increases from 30 percent to 86 percent. This should not be regarded as the most reliable predictor of streamflow loss because, as previously described, the integrated modeling approach should be used for that purpose. The model results are described here because they demonstrate that the hydraulic conductivity of the bedrock is an important model variable in assessing streamflow loss.

Using the integrated modeling approach, and examining the 10th percentile low flow and high hydraulic conductivity scenario, Crooked Creek is expected to go dry above American Creek during the low flow season (Table 3.5-26 in Section 3.5, Surface Water Hydrology). Under this scenario and compared to the low flow base-case hydraulic conductivity scenario, the maximum summertime predicted reduction in flow increases from 26 percent to 61 percent and the annual average predicted reduction in flow increases from 22 percent to 46 percent. This verifies that the hydraulic conductivity of the bedrock aquifer is an important parameter of the model. Use of the base case results, even though they remain probable, should include consideration that other potential outcomes of the model, some quite different, are plausible. This is because bedrock hydraulic conductivity tends to vary from place to place by about three orders of magnitude and model projections based on a single realization of these values at or near the mean values have significant uncertainty.

Similarly, a second sensitivity analysis was conducted that simulates hydraulic conductivity zones associated with known faults. Observations in the areas of the faults have not indicated that these faults exhibit high hydraulic conductivity and the base case model did not assign values to faults any different than the surrounding rock. Conceptually, this scenario evaluates the situation where faults subcrop beneath Crooked Creek and extend for some distance away from the creek. Similarly to the high-hydraulic conductivity analysis described above, the calibration worsens under this scenario. The maximum percent reduction in flow of Crooked Creek at Station CCBO during wintertime increases from 30 percent to 83 percent of flow under this scenario. The maximum summertime reduction in flow increases from 9 percent to 16 percent and the maximum average reduction in flow increases from 20 percent to 49 percent.

Together, these scenarios demonstrate that the model results showing impacts to Crooked Creek should be regarded as uncertain and that the analysis of project effects should include scenarios other than the base case (e.g., the sensitivity analyses described above). Should most or all of the water (at least during winter) in Crooked Creek be diverted by groundwater conditions similar to these sensitivity analysis scenarios, the loss of streamflow and creek habitat could be of high magnitude and extend to a more regional distance downstream (but still limited by the mouth of Crooked Creek). The effect would be long-term, lasting as long as the dewatering system is active during mine operations and with gradually declining impacts, through the closure period as the groundwater system recharges. Permanent residual impacts caused by the permanent lowering of lake levels below the level of Crooked Creek would be of low magnitude.

Permanent Camp Water Use and Domestic Wastewater Disposal

Potable water for the permanent camp at the mine site would be obtained from four water wells that would be drilled at the permanent camp site. These wells would be designed to supply a volume up to approximately 50 gpm during operations. Approximately 30 gpm would continue to be supplied from the wells near the construction camp for potable plant use. Similar to construction camp water use, impacts would be local, long-term (lasting for the 27.5-year duration of the camp with reduced impacts extending into the closure period), and low magnitude (usage would not create changes in water quantity outside of minimal variation levels). Water rights for the permanent camp have been applied for in the amount of 50 acre-feet / year (31 gpm on a continuous basis).

Domestic wastewater would be piped to the TSF during operations, with no impact on groundwater different from items described separately in the TSF section below.

Snow Gulch Reservoir

Snow Gulch reservoir is planned to be operated near a reservoir-full condition during most operational periods when water from the reservoir is not needed. The water table near the reservoir would remain in an elevated position during this period and the conditions described during the construction period would remain.

Tailings Storage Facility

The TSF would be lined and consequently would be expected to have little or no leakage to groundwater. In the event that some leakage occurs studies have shown that a design liner defect ratio of 0.16 in^2 of flaw per acre is conservative for evaluating potential liner leakage rates (Giroud and Bonaparte 1989; Giroud et al. 1994). Modeling studies have estimated that up to 18 gpm of water would leak from the facility using this defect ratio. The TSF would be designed with a rock underdrain that would serve two purposes: 1) capture and direct any TSF leakage to a Seepage Recovery System (SRS) located immediately downgradient of the TSF dam; and 2) collect groundwater from areas upgradient of the TSF and direct it to the SRS as TSF underflow. While predicted underflow would vary somewhat during operations as a result of varying pit dewatering and other factors, at mine closure, the quantity of groundwater captured by this system is estimated to be 450 gpm, of which 18 gpm is estimated to be from the TSF (BGC 2014c; b). After closure, similar quantities of flow would persist. The results of various sensitivity analysis scenarios suggest that groundwater flows to the underdrains could range from 200 gpm to 680 gpm (BGC 2014c).

The SRS would consist of an unlined pond, pumps, pipeline, ditches and monitoring / seepage recovery wells, the locations of which are shown in Figure 2.3-7 (Chapter 2, Alternatives). The SRS pond would function as a collection point to receive flow from groundwater entering the underdrain and any TSF leakage. A sump would be completed into bedrock within this pond and the water level would be maintained below the level of the base of both the underdrain and the overburden on the downslope side of the pond (Weglinski 2015d). Pre-development, the static water level in the pond area is predicted to be above the bedrock / overburden contact. Pumping from the pond would be sufficient to create hydraulic containment and prevent leakage to groundwater. Using hydraulic containment within the unlined SRS pond would allow the collection of underflow from a broader area than just the underdrain to ensure hydraulic containment.

Four monitoring / seepage recovery wells would also be installed; two on each side of Anaconda Creek, downgradient of the tailings pond. On each side of Anaconda Creek, one deep (328 feet) and one shallow (164 feet deep) well would be installed. The wells would be capable of pumping 45 to 90 gpm each and would discharge to the SRS pond. The purpose of the wells is to 1) monitor groundwater quality to verify that groundwater does not deteriorate and 2) to create a completely closed flow system to capture any potential leakage from the TSF or SRS pond into the groundwater system if water quality deteriorates. This system would essentially constitute a backup hydraulic containment capability that, in the absence of TSF leakage, would not be used. The quality of water from the pond and wells would be monitored to determine the operational requirements of the system. Excess water in the pond would be pumped either to the process plant or directly into the TSF.

Water rights for the diversion of groundwater via the TSF underdrains and seepage recovery wells have been applied for in the amount of 2,841 acre-feet/year (1,761 gpm on a continuous basis).

The effects of the TSF on groundwater resources in the immediate vicinity of the TSF would be:

- Local capture and diversion of approximately 730 gpm (two years before operations begin) to 440 gpm (at Year 25) of groundwater flow from its natural flow system to a rock underdrain under the TSF and discharge to a newly constructed SRS pond. The water would then be incorporated into the water use/recycling system of the processing plant, the AWT system, and the TSF. Pumping capacity from the SRS will be sized during the design phase to accommodate the largest anticipated inflows to the SRS.
- Pumping of up to 360 gpm of groundwater from four monitoring/seepage recovery wells, if needed as determined by water quality sampling. The liner under the TSF, assuming it functions as intended, would prevent seepage from the TSF, and the SRS pond would collect water from the underdrain such that the wells would not need to be pumped. Should it occur, the pumping would create a local cone of depression around the wells that is designed to capture all leakage from the SRS; however, it would also capture other groundwater. This water would also be incorporated into the water use/recycling system of the processing plant, AWT, and TSF pond.

Downstream of the TSF, the flows of Anaconda Creek and Crooked Creek would be diminished by the diversions described above, as well as by the diversions of surface water flows into the TSF. The combined diversions of groundwater and surface water are expected to reduce average flow in Anaconda Creek at its confluence with Crooked Creek by approximately 30 percent at Year 20 of mining (Table 3.6-2, SRK 2012b). This is because additional water enters Anaconda Creek below the TSF and SRS. The effects of these diversions are expected to be of low to medium magnitude (i.e., alterations in flow quantity and location, although flow systems partially maintained), local extent, and permanent.

The hydraulic containment system of the SRS would require monitoring, analysis, operation, periodic repair, and management to assure its continuing function and effectiveness. During operations, on-site observations and flow measurements would lead to rapid identification of pump failure problems and use of backup pumping capacity in the event of system failure and the avoidance of the release of water to the environment. Considering the long duration of pumping during closure and post-closure conditions, however, (especially during winter when staffing levels are reduced) the harsh climate, the remote location, and the number of task-critical components, the possibility of a pumping failure is plausible and the consequences of a failure merit examination. Long-term monitoring and maintenance is planned which would minimize such risk. The location of the facility in a different drainage than the pit and other facilities means that reliance on a gravity-driven backup diversion or storage system is likely not feasible.

Calculations suggest that if the SRS pumping system were to go completely off-line, the SRS would likely fill to overflowing and / or lose hydraulic containment with respect to groundwater in approximately two weeks, although there are many variables such as time of year and amount of drawdown at the start of the failure that could affect this calculation. Still, considering these variables, this is a very short timeframe in which to identify a problem, diagnose the cause, acquire any necessary components, and effect repairs, especially if it occurs during winter conditions during closure or post-closure when staffing levels are lower than during operations. Analysis of the potential quality of water in SRS shows that the water would exceed relevant standards for several parameters (see Section 3.7, Water Quality).

If hydraulic containment of the SRS system is lost, it is likely that contaminated groundwater would enter the flow system towards Crooked Creek and it would be impractical to retrieve because it would relatively quickly flow outside of the radius of influence of the SRS wells. Natural groundwater flow patterns in this area indicate that groundwater would eventually discharge to the lower reaches of Anaconda Creek and to Crooked Creek, however natural attenuation processes in groundwater could slow and eventually halt the flow of contaminated groundwater. There are many factors that influence this process and the timeframe for groundwater to be restored to pre-development conditions is expected to be lengthy but unknown. Also, should contaminated groundwater eventually reach surface water, the rate of groundwater discharge would be relatively low and may be completely masked by dilution from surface water flow.

The release of SRS water to the environment during the approximately 52-year period during which the covered tailings would drain and consolidate would only occur in the event of a pump failure greater than two weeks in duration, and such an event is considered unlikely but plausible under Alternative 2. The impacts of this (as described in Section 3.7, Water Quality) would be low-probability but high in magnitude, local, and long-term in duration, affecting a common to important resource.

Waste Rock Facility

The WRF would be located in the American Creek valley upstream of the proposed pit. The WRF would be unlined, and long-term modeling shows that a portion of rainfall and snowmelt would infiltrate through the surface of the facility and flow out of the bottom of the waste rock pile (O'Kane Consultants, Inc. 2009). Beneath the facility, a rock underdrain would be constructed to direct some of this water into the lower contact water pond near the toe of the facility. The WRF and the rock underdrain system have the potential to pass water into the underlying groundwater because they are not underlain by liners. The flow of this contact water is further described in Section 3.7, Water Quality. However, the location of the WRF in the surface water and groundwater flow systems that drain into the pit lake create a closed system whereby the effects on groundwater are limited to the immediate vicinity of the WRF and the small area between the WRF and the open pit. Modeling analysis has shown that groundwater beneath and downgradient of the WRF would be captured by the pit dewatering system and, after the system is deactivated at the end of mining operations, by the groundwater flow system discharging into the pit lake (BGC 2014c). The regular active pumping of water from the pit lake would effectively prevent contaminated groundwater from flowing away from the pit.

South Overburden Stockpile

The South Overburden Stockpile (SOB) (Figure 2.3-6, Chapter 2, Alternatives) would contain terrace gravel and colluvium materials excavated from the open pits which are considered potentially metal leaching. Seepage and surface runoff that comes into contact with materials stored in the SOB may require collection and treatment. Surface and seepage runoff from the stockpile will be captured by a sediment pond and pumped to the Lower CWD.

During operations, the inactive faces of the stockpile will be progressively reclaimed to minimize the potential for surface entrainment and infiltration. All materials placed in the SOB will ultimately be returned to the WRF over the course of mine operations and placed either as the base cover layer for final reclamation of the WRF or used as internal capping materials for the PAG cells.

Water from the sediment pond has the potential to leak into groundwater. The sediment pond is located near the edge of the cone of depression created by pit dewatering, so that the direction of groundwater flow during at least part of the operations period is assumed to be towards Crooked Creek. The quantity of groundwater that may flow away from the sediment pond would be relatively low as a result of the small size of the facility, the limited collection of water in the sediment pond, the relatively low hydraulic conductivity of the colluvial deposits at the site, the accumulation of silty sediments in the pond, and the temporary presence of the SOB soils.

Water percolating through the SOB also has the potential to enter groundwater and flow towards Crooked Creek. The quantity of water entering groundwater through this process may also be low as a result of the small size of the facility, the relatively low hydraulic conductivity of the SOB soils and the underlying soils, and the temporary presence of the soils. The fate and transport of this groundwater is uncertain; however, the impacts on Crooked Creek may be minimal or nonexistent as a result of natural attenuation processes such as sorption, dilution, and dispersion.

Several potential mitigating measures are described in Chapter 5, Impact Avoidance, Minimization, and Mitigation, including conducting further studies such as fate and transport groundwater modeling during final design to quantify the expected rate of seepage loss and impacts to Crooked Creek; creating a system of hydraulic containment for the sediment pond; installing a liner under the pond, the SOB soils or both; and installing groundwater monitoring wells. Also, during the operational period, maintenance, monitoring, and contingency plans should be used to ensure that the pond does not overflow as a result of pump failure. Following removal of the SOB soils, sediment accumulations in the sediment pond should be removed to eliminate a potential future source of groundwater contamination.

Closure, Reclamation, and Monitoring

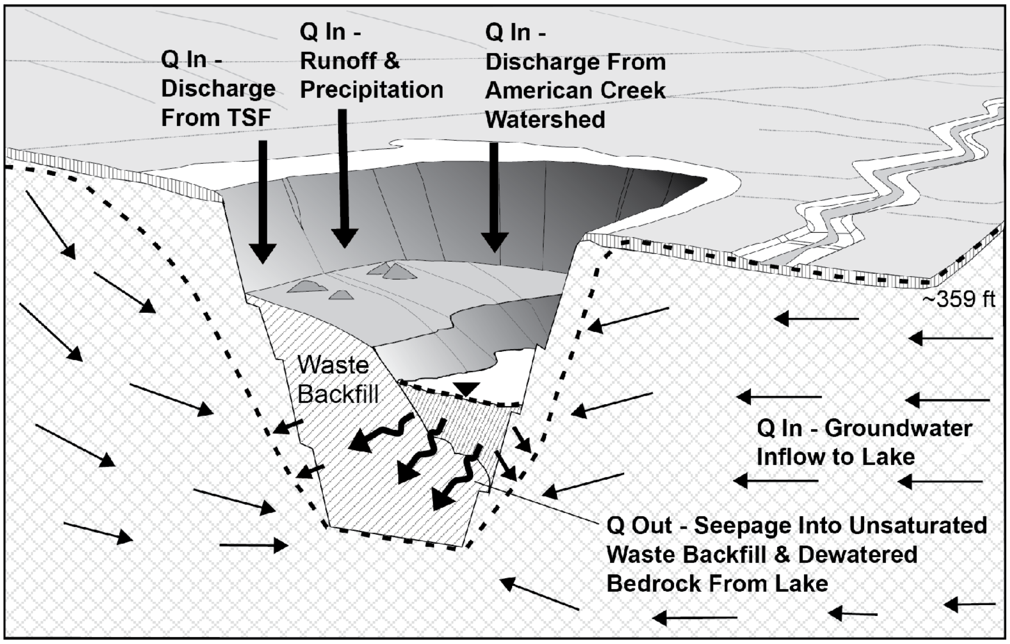
Pit Lake

After completion of mining operations, the pit dewatering system would be turned off. The pit lake would fill to its maximum design water level in approximately 52 years from groundwater inflow, runoff from the American Creek watershed, and TSF discharge (BGC 2015g). Figure 3.6-9 shows the conceptual model of water flows during the period of pit lake filling. During the entire 52-year filling period, water would also flow from the pit lake into the dewatered bedrock and waste rock backfill in the pit. The rate of this water flow would be greatest during the first 8 years of pit lake filling, declining from about 2,300 gpm to about 1,000 gpm (Figure 3.6-10). After 8 years and up to when the lake pit fills, the rate of water flowing out of the pit into groundwater would gradually decline from about 1,000 gpm to 0 gpm. Water flowing out of the lake would go into storage by filling pore spaces in the backfill and nearby bedrock. After the pore spaces are filled, the direction of groundwater flow of this water would be towards the pit lake. The lateral extent of this temporary groundwater flow reversal is expected to be localized and would be hydraulically contained by groundwater flowing towards the pit lake as shown in Figure 3.6-9. Thus, overall hydraulic containment of contact groundwater would still be maintained during this period due to the greater head from groundwater outside this zone and flow towards the pit lake. Water levels would be monitored in wells near the pit to confirm that this process is occurring.

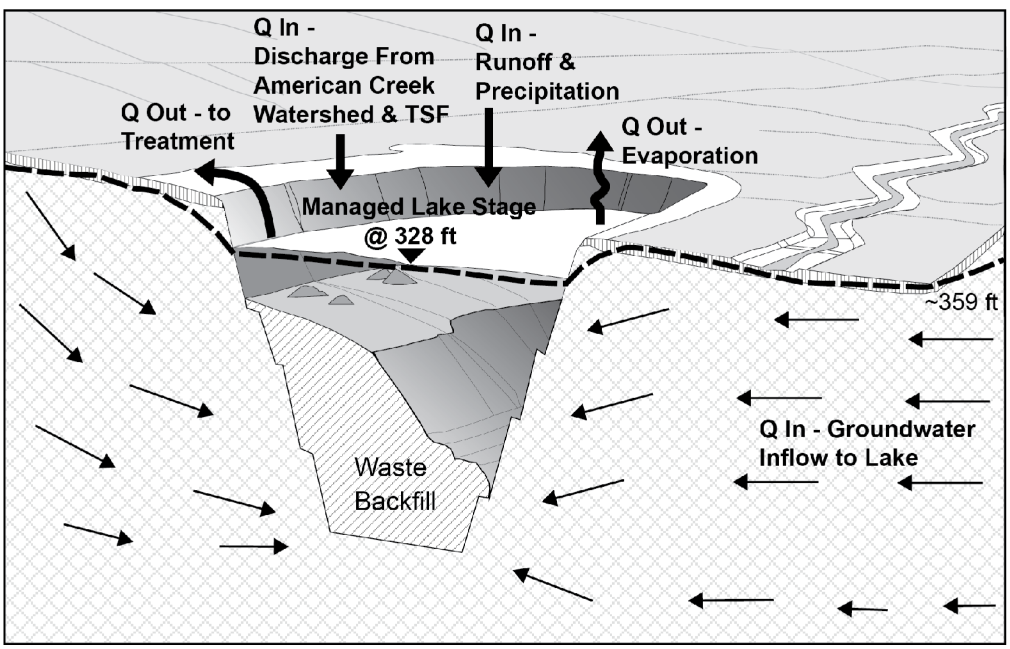
During the entire pit-filling period, groundwater would also flow into the pit at rates ranging from 400 to 700 gpm from seasonal recharge to the groundwater system. Natural recharge to groundwater from the land surface and recharge to groundwater from pit lake water would cause the cone of depression to slowly recover. An analysis by Lorax (2012a) showed that, even under various scenarios, the predicted water quality of the lake will not meet applicable water quality criteria without treatment. Thus, a water treatment and lake level management plan has been developed. Under this plan, the maximum design water level of the pit lake would be approximately 10 to 30 feet below the level of Crooked Creek (adjacent to the open pit). The pit lake level would be managed by seasonal pumping, treating, and discharging of water to Crooked Creek to prevent unmanaged flow from the pit lake to Crooked Creek. As a result of these seasonal activities and also because of seasonally-variable hydrologic inputs to the lake, the water level in the pit lake is expected to fluctuate at levels below the maximum design water level.

Two sensitivity analyses scenario simulations of the groundwater model resulted in model variations of 13 or more years for the predicted fill time for the pit lake. By increasing groundwater recharge and streamflows by a factor of two throughout the model in order to explore a wet climate scenario, the pit lake was calculated to fill in 26 years following the cessation of mining (BGC 2015i). By increasing the hydraulic conductivity of bedrock by a factor of five (and using the base case recharge and streamflow values), the model predicted a fill time of 39 years, 13 years quicker than the base case scenario of 52 years (BGC 2015i). These scenarios serve to illustrate the range of uncertainty in the base case model findings on the length of time needed to fill the pit lake.

The groundwater model also shows that groundwater is expected to flow into the pit lake from all directions during all seasons after the pit lake has achieved its maximum design water level. The WRF would be located within the groundwater catchment basin of the pit lake and any leakage beneath the facility would discharge to the pit lake and not enter other surface water bodies in the area. Water from the pit lake would be treated prior to discharge.



Early Pit Lake Filling Period



After Pit Lake is Full

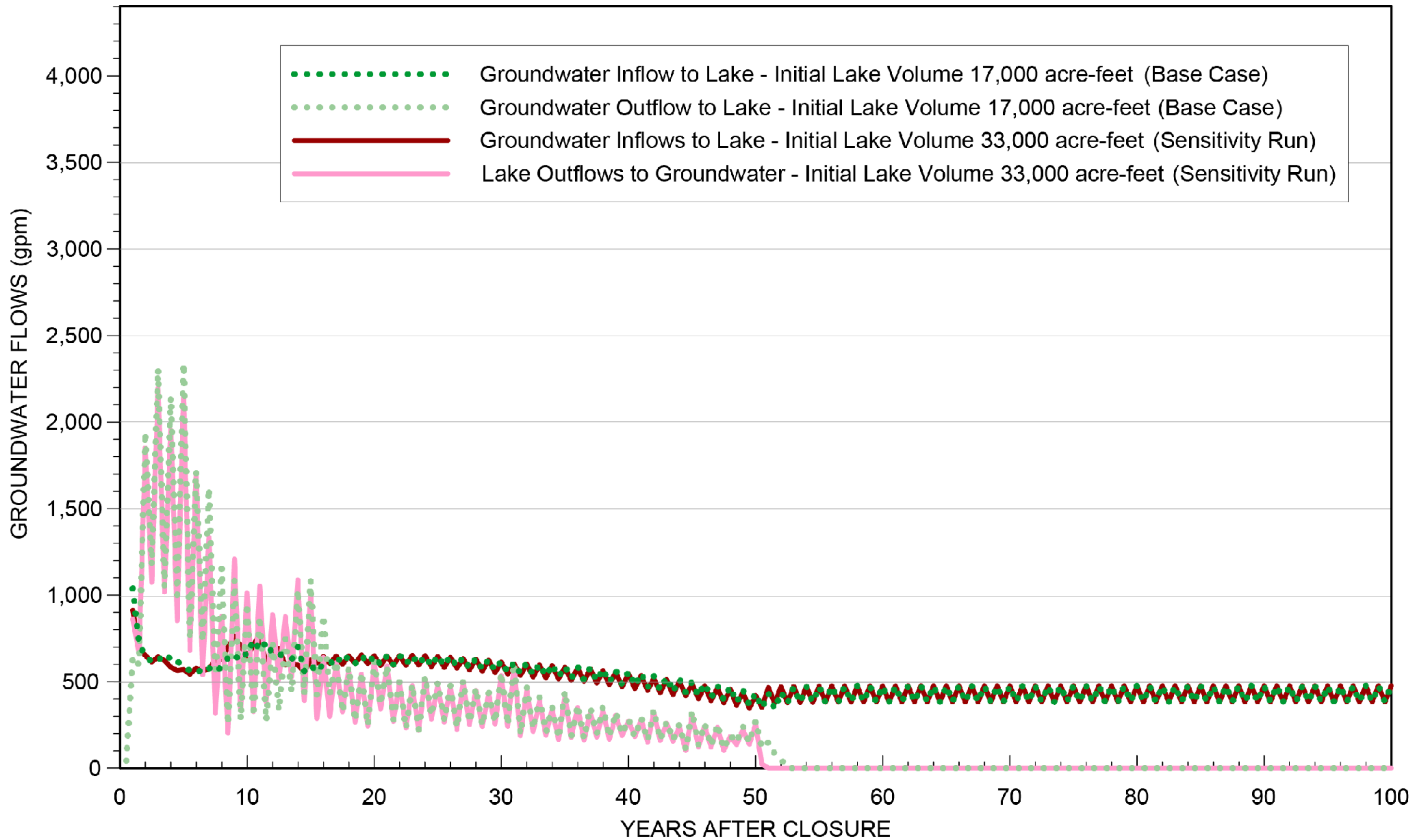
Q = Flow
Data Source: BGC 2014c

DONLIN GOLD
PROJECT EIS

GROUNDWATER SYSTEM AT
PIT LAKE IN CLOSURE PERIOD

NOVEMBER 2015

FIGURE 3.6-9



Data Source: BGC 2015g

DONLIN GOLD PROJECT EIS

PREDICTED GROUNDWATER FLOWS TO AND FROM PIT LAKE

NOVEMBER 2015

FIGURE 3.6-10

There would also be an ongoing change in the discharge/recharge relationship between Crooked Creek and groundwater near the pit. After stabilized water levels are achieved (i.e., after the filling of the pit lake to the design level), Crooked Creek would lose water to the groundwater system, opposite of the pre-mining flow system of groundwater providing recharge to the creek.

Separately, Crooked Creek would also experience changes in flow from the diversion of American Creek into the pit lake. Water would be diverted into the pit lake during both winter and summer, and then the pit lake water treatment plant would treat and discharge this water back to Crooked Creek during the summer. These changes are described more completely in Section 3.5.3.2.1, Surface Water Hydrology.

Thus, while changes to the groundwater flow system would be permanent, the magnitude of impacts is expected to be low to medium (i.e., flow systems levels are maintained mostly within the limit of natural variation), and the effects would be localized around the immediate vicinity of the pit lake and some distance down Crooked Creek.

Tailings Storage Facility

Water stored in the TSF at the end of mining operations would be pumped into the pit lake. After closure and reclamation, the liner beneath the tailings and on the upstream face of the dam would remain intact; therefore, the expected rate of seepage would not change substantially from the operational conditions. Groundwater discharge to the TSF underdrain would vary seasonally, from an average of 370 gpm during winter to 440 gpm during summer (BGC 2014c). Monitoring would continue into the post-closure period, and if the water quality is shown to meet water quality standards, then the SRS would be decommissioned. SRS water would be pumped to the pit lake until such time as it meets water quality standards (see Section 3.7, Water Quality). The local diversion of groundwater beneath the TSF through the rock underdrain would continue permanently.

After reclamation of the surface of the TSF is complete, surface water flows in the Anaconda Creek valley upstream of the tailings dam would be diverted into the Crevice Creek watershed. This would reduce groundwater recharge in the Anaconda Creek Valley compared to pre-development conditions, and result in a net increase in flow in Crevice Creek and a decrease in flow in Anaconda Creek downstream of the tailings dam. Because Crevice Creek and Anaconda Creek both discharge into Crooked Creek, the effects of these changes in flow would be considered local and would not be expected to extend any further down Crooked Creek than the confluence with Crevice Creek. All of these impacts are expected to be of low magnitude (small creeks commonly exhibit large natural variations in flow).

Waste Rock Facility

The effects of the WRF on groundwater during and after closure and reclamation would be similar to what they would be during operations. Capping and vegetation placed during closure would likely reduce seepage rates through the facility, but the overall effect on groundwater resources would be minor. Modeling analysis has shown that groundwater beneath and downgradient of the WRF is captured by the pit lake after the lake has achieved its highest design water level during both summer and winter conditions (BGC 2014c).

Snow Gulch Reservoir

During the closure process, the Snow Gulch Reservoir would be breached and groundwater conditions in the vicinity would gradually return to pre-development conditions.

Summary of Mine Site Impacts

Mine pit dewatering at a maximum planned groundwater pumping rate of 2,600 gpm would result in low to high (during construction and operations) and low to medium (during closure) magnitude changes in the local groundwater flow system. Most of the pumped water would be used for process water and excess water would be treated and returned to Crooked Creek. Water would seep from Crooked Creek and tributaries near the pit into the pit dewatering system, although most of the time the amount would be a small proportion of the surface flow. During winter conditions and under low flow (i.e., dry year) and high hydraulic conductivity scenarios, a majority or all of the flow in Crooked Creek in some segments could leak into groundwater and be diverted into the pit groundwater dewatering system. The highest intensity groundwater impacts would be during the period of active mining. However, some effects to the groundwater flow system would be permanent. The pit lake level will be managed to remain below the level of water in Crooked Creek, thereby inducing groundwater flow from the creek to the lake at all times. This constitutes a permanent reversal of groundwater flow directions towards the pit lake rather than towards local streams as occurs under pre-mining conditions.

Infiltration of water through the SOB and pumping of the sediment pond could result in low intensity impacts to groundwater flow and potential migration of contact water towards Crooked Creek. Potential impacts to groundwater quality at the SOB are discussed in Section 3.7, Water Quality.

After the pit lake achieves its maximum managed level, the amount of leakage from Crooked Creek would be a small percentage of the overall flow in the creek because the groundwater gradients would be very low compared to those present during mining, and the magnitude of the effects would be considered low. Groundwater resources would be affected in a local area of approximately 20 square miles encompassing the proposed pit, WRF, and TSF; however impacts would mostly remain on the east side of Crooked Creek. Groundwater is a common to important resource in the area, in that, while abundant, its use, diversion, and discharge is regulated by state laws and regulations.

3.6.2.2.2 TRANSPORTATION FACILITIES

Port facilities planned for the Angyaruaq (Jungjuk) Port are anticipated to require development of water supply systems for offices and warehouses.

Construction

Construction of a potable water well would be required at the Angyaruaq (Jungjuk) Port. The well would be constructed in compliance with State public well construction standards. Water rights have been applied for from a well in the amount of 0.55 acre-feet/year (0.34 gpm on a continuous basis) and all conditions would be complied with.

Indirect impacts are expected at the Bethel and Dutch Harbor ports, where facilities would be operated by third parties. At the Bethel Port, facilities would most likely be hooked up to the

Bethel public water and wastewater systems, and the increased demand would be within the capacity of the systems (low intensity impact). Should on-site well water be needed, deep subpermafrost aquifers are assumed to be available, similar to water resources currently tapped by other users in the area (Section 3.6.1.2.2). Any wells drilled would be constructed in compliance with State public well construction standards. Authorization to use water would be obtained from the State of Alaska, and all permit conditions would be complied with.

Operations and Maintenance

The potable supply well would be operated at the Angyaruaq (Jungjuk) Port for the duration of project operations. The quantity of water used would create low intensity impacts (use levels would make up a small portion of the capacity of local or regional aquifers). These localized impacts would be considered long-term in duration.

Closure, Reclamation, and Monitoring

At project closure, the potable water well at the Angyaruaq (Jungjuk) Port would be abandoned according to ADEC regulations. Any low-intensity impacts on local and regional aquifers would be restored to pre-development conditions.

Summary of Transportation Facilities Impacts

Anticipated effects from the construction, operations, and closure of transportation facilities associated with Alternative 2 would be limited to small stresses on the aquifers tapped by water supply wells for new port facilities. These low intensity stresses are anticipated to be within the capacity of aquifers to support without impacting other water users or nearby surface water resources. Impacts would be long-term in duration (lasting the life of the project), local in extent (in the close vicinity of the wells constructed or pumped), and common to important in context. It is anticipated that there will be no indirect effects on groundwater as a result of the proposed transportation facilities.

3.6.2.2.3 NATURAL GAS PIPELINE

Construction

Groundwater and surface water resources are closely connected along portions of the pipeline route - primarily near stream crossings or at proposed water take points. In many other locations, groundwater occurs within the planned pipeline burial depth (CH2M Hill 2011b; SRK 2013b). Groundwater would also be used for camp water supply sources. Other potential uses of water for construction purposes include hydrostatic pipeline testing, ice road construction, HDD and installation, dust suppression, and other uses.

Potential direct impacts to groundwater during the construction phase of the natural gas pipeline could result from the installation of the pipeline at river and stream crossings, and temporary disturbance of groundwater during trenching activities. Rivers and streams on the pipeline route would be crossed primarily by open cutting in the winter months when flows are lowest, and disturbance of the river, stream banks, and local groundwater would be minimized, or by using HDD technology. BMPs and other mitigation measures would be used to minimize possible impacts during this phase (see Section 3.2, Soils).

Spring-fed areas tend to be important for spawning and overwintering fish because groundwater discharge usually occurs at a relatively steady rate and temperature in river bottomland environments. River bottoms commonly represent the natural discharge area for large groundwater flow systems of both local and regional scale. Groundwater tends to flow most vigorously through permeable sands and gravels into rivers. Along the project alignment, large alluvial fans and river alluvial deposits are present through which groundwater flows. The driving force to these groundwater discharges are head gradients.

The scale of disturbance caused by the pipeline is likely to be very small in comparison to the scale of the groundwater aquifers and head gradients that drive groundwater discharge, and would not affect those large-scale aquifers and head gradients.

At specific localities, the pipeline plan of development addresses the possibility of intercepting groundwater flows. Dewatering of the trench may be necessary to emplace the pipe; however this by itself would present only a very transient and low magnitude disturbance to the groundwater flow field.

If the trench breaches into a water-producing aquifer and creates a new flow path for groundwater to follow, the plan of development calls for emplacing trench plugs consisting of sprayed and solidified foam that would be used to prevent such flow and restore the natural blockage of flow. There is a solid reason to do this because turbulent flow of groundwater along or underneath a pipeline can erode sediment particles and result in pipeline settlement.

In cases where the trench is installed in a permeable aquifer and there is naturally a lot of groundwater flowing through the area, trench plugs would also be installed. These plugs would have the effect of causing water to divert a few feet around the trench and pipeline and groundwater would continue on its flow path in the aquifer towards its discharge locations with minimal disruption.

In areas where substantial groundwater is not encountered, the potential for affecting flows of spring water in nearby areas is extremely low because concentrated areas of groundwater flow that contribute to the springs would be localized and would have been missed by the pipeline.

In all cases, the potential for disruption of springs in rivers and streams is very low either because the pipeline does not encounter groundwater (and misses disrupting the flowpath), or because trench plugs are installed to minimize the potential for the pipeline trench to create a preferred pathway and alter the natural flow of groundwater.

Water used by the project would be pumped or diverted and discharged in conformance with permit conditions. All potential water extraction sites, other than camp use, are from surface water sources. As a result, potential low intensity effects on groundwater would be localized and temporary in duration (lasting only during the construction phase).

Potential effects on groundwater would also occur from use of water supply wells for camp use. Peak numbers of construction personnel is estimated to be 650 people. At 70 gallons per day (gpd) / person, this is 45,500 gpd or 32 gpm, spread across several camp locations. These camps are in remote locations, however, and the quantity of water use would likely be small compared to the quantity of groundwater resource readily available. Resultant low intensity impacts would be localized around the wells, and temporary in duration.

Operations and Maintenance

Operation and maintenance activities associated with the natural gas pipeline under Alternative 2 would have no direct or indirect impacts on groundwater hydrology.

Closure, Reclamation, and Monitoring

Closure, reclamation, and monitoring activities associated with the natural gas pipeline would have no direct or indirect impacts on groundwater hydrology.

Summary of Natural Gas Pipeline Impacts

Anticipated effects from the construction, operation, and closure of the natural gas pipeline under Alternative 2 would be limited to temporary small stresses on the aquifers tapped by water supply wells for camp facilities, and temporary disturbances associated with pipeline construction. Disturbances to groundwater are anticipated to be relatively small compared to the amount of groundwater in the aquifers. Impacts would be of low intensity and would be temporary in duration, lasting only as long as the period of construction. Groundwater effects would also be local in extent (in the close vicinity of the wells constructed or pumped). There would not be any indirect effects on groundwater expected as a result of the proposed natural gas pipeline.

3.6.2.2.4 CLIMATE CHANGE

Predicted overall increases in precipitation and changes in patterns of surface water distribution have the potential to influence the projected effects of the Donlin Gold Project on groundwater. These effects are tied to changes in water resources as discussed in Section 3.26.4.2.2.

3.6.2.2.5 SUMMARY OF IMPACTS FOR ALTERNATIVE 2

Table 3.6-4 outlines direct impacts to groundwater at the mine site, transportation facilities, and pipeline components under Alternative 2 would range from low intensity (e.g., groundwater flow changes at the SOB, or small stresses to aquifers tapped for water supply along the pipeline or transportation facilities) to high intensity (e.g., mine pit dewatering). Mine pit dewatering (at a maximum planned groundwater pumping rate of 2,600 gpm) would create up to 1,600 feet of drawdown in the local groundwater flow system. A cone of depression would be created around the open pit, generating high intensity impacts to the groundwater flow system near the pit by causing groundwater to flow toward the open pit from all sides. Groundwater would no longer discharge to Crooked Creek in the vicinity of the pit; as a result, flows in Crooked Creek and the lower reaches of creeks adjacent to the pit would be reduced during mine operations. The integrated groundwater-surface water modeling results indicate that wintertime streamflow may be reduced by 19 to 100 percent above American Creek near the end of mining, depending on conditions. Low flow (i.e., dry year) conditions and high hydraulic conductivity aquifer conditions result in the most streamflow loss. At the end of mining operations when the pit dewatering system is deactivated, the water table will begin to recover and intensity of impacts on creeks will be reduced. The most intense groundwater hydrology impacts would be long-term (lasting for the life of the project at the mine site), although there would also be low intensity, temporary impacts associated with the construction of the transportation facilities and natural gas pipeline. The groundwater that is impacted is considered common to important in context. Net overall impacts would be considered minor; however, impacts could be moderate due to substantial uncertainties inherent in estimating bedrock conditions and modelling groundwater flow.

Table 3.6-4: Summary of Impacts to Groundwater Hydrology for Alternative 2

Impacts	Impact Level				
	Magnitude or Intensity	Duration	Geographic Extent	Context	Summary Impact Rating[1]
Mine Site					
Change in water use	Low	Long-term	Local	Common to Important	
Change in water table and potentiometric surface	Construction/Operations: Low to High Closure: Low to Medium	Construction/Operations: Long-term Closure: Permanent	Local	Common to Important	
Summary	Low to High	Long-term to Permanent	Local	Common to Important	Minor to Moderate
Transportation Facilities					
Change in water use	Low	Long-term	Local	Common to Important	
Summary	Low	Long-term	Local	Common to Important	Minor
Natural Gas Pipeline					
Change in water use	Low	Temporary	Local	Common to Important	
Summary	Low	Temporary	Local	Common to Important	Minor

Notes:

The summary impact rating accounts for impact reducing design features proposed by Donlin Gold and Standard Permit Conditions and BMPs that would be required. It does not account for additional mitigation or monitoring and adaptive management measures the Corps is considering.

These effects determinations take into account impact-reducing design features (Table 5.2-1, Chapter 5, Impact Avoidance, Minimization, and Mitigation) proposed by Donlin Gold as well as Standard Permit Conditions and BMPs (Section 5.3) that would be implemented. Design features that are most important for reducing impacts to groundwater hydrology include the following:

- Water management planning at the mine site would assist in controlling the flow of groundwater at the pit and other major facilities (WRF, TSF), as well as controlling the potential effects of groundwater flow on water quality downgradient of the mine. This would be accomplished through design elements such as dewatering wells, collection of groundwater infiltration through and around the TSF at the SRS pond, and lake level maintenance following closure. A variety of groundwater monitoring activities would also be planned;

- With the exception of localized effects in the first 8 years following closure in the deep bedrock aquifer, dewatering during operations and maintenance of pit lake levels during post-closure would maintain groundwater flow gradients towards the pit, so that impacted mine contact water would not flow away from the mine site; and
- The project design includes installation of pipeline components primarily in the winter months when a frozen active layer is present, and disturbance of local shallow groundwater would be minimized.

Standard Permit Conditions and BMPs related to groundwater hydrology include:

- Controls on contact groundwater flow, treatment, and discharge in APDES water quality permits required under the CWA;
- Oversight of dam seepage flow under ADNR dam safety permitting; and
- Financial assurance under ADNR permitting that would fund groundwater containment at the pit lake and SRS in post-closure.

3.6.2.2.6 ADDITIONAL MITIGATION AND MONITORING FOR ALTERNATIVE 2

The Corps is considering additional mitigation (Table 5.5-1, Chapter 5, Impact Avoidance, Minimization, and Mitigation) to reduce the effects presented above. Additional mitigation measures related to groundwater include the following:

- Proposed diversion channels and sediment pond at the SOB may not be adequate to capture groundwater that could become contaminated from seepage/leachate and flow towards Crooked Creek. One of the following options should be considered for this facility:
  - Hydraulic containment (deep sump as part of sediment pond) and downgradient monitoring wells. The feasibility of digging a deep sump should be evaluated further during design work;
  - Physical containment (liner beneath SOB and sediment pond); or
  - Additional studies during design work (fate and transport groundwater modeling) to demonstrate a lack of substantial groundwater volume that would result in no major impact on the creek, as a result of natural attenuation of a small temporary slug of contaminated groundwater.

The Corps is considering additional monitoring and adaptive management (Table 5.7-1, Chapter 5, Impact Avoidance, Minimization, and Mitigation) to reduce effects on groundwater. These include the following:

- As a result of the recognized uncertainty of model results, the groundwater flow model should be reexamined 3 years after the commencement of pit dewatering to minimize uncertainty about dewatering effects, with a 5-year review frequency thereafter, or when noteworthy unexpected conditions are encountered. Unexpected conditions should be used to revise projections and adjust management plans as needed. As required by permit conditions, relevant groundwater data (such as production rates and water table levels) should be collected as mining progresses to facilitate model revisions;

- Based on performance of the Seepage Recovery System in operations, consider an additional well field and/or pond that acts as a secondary containment system to the SRS downgradient of the SRS. This measure should be considered to minimize the likelihood of an extended pumping failure in Alternatives 2 and 5A; and
- To minimize the effects of climate change and considering the uncertainty of current projections, reexamine the continuing applicability of key portions of the water balance model on approximate 10-year intervals as determined by the data collected and operational or closure conditions and experiences. For example, current mine plans for the pit lake during closure indicate that the water level would be monitored and pit lake model recalibrated as data become available. It is recommended that climate change precipitation predictions also be reevaluated periodically in post-closure, and incorporated into water balance and groundwater model updates, in order to adequately anticipate climate change effects on pit filling and other project structures such as reclaim components.

If these mitigation and monitoring measures were adopted and required, uncertainties in the range of summary impact ratings for groundwater would be reduced, and the ratings themselves could be reduced to either minor overall, or minor to moderate overall, depending on bedrock and groundwater flow conditions encountered after the mine is built.

3.6.2.3 ALTERNATIVE 3A – REDUCED DIESEL BARGING: LNG-POWERED HAUL TRUCKS

The expected effects of this alternative are similar to those discussed under Alternative 2. The reduced barging of diesel fuel associated with Alternative 3A would create lower intensity impacts to groundwater resources than Alternative 2 by reducing the exposure of groundwater to potential spills or leaks from diesel fuel transport and storage systems along the Kuskokwim River corridor and at the mine site (see Sections 3.24.6.7.2, Spill Risk and 3.7, Water Quality).

3.6.2.3.1 SUMMARY OF IMPACTS FOR ALTERNATIVE 3A

Direct and indirect effects for Alternative 3A would be the same as discussed under Alternative 2. Impacts associated with climate change would also be the same as those discussed for Alternative 2. The implementation of Alternative 3A would have minor to moderate impacts on groundwater in the proposed Project Area.

Design features, Standard Permit Conditions and BMPs related to groundwater hydrology are described in Alternative 2. Additional mitigation and monitoring measures are also described in Alternative 2. If these mitigation measures were adopted and required, the summary impact rating would similar to Alternative 2, minor to moderate, depending on actual bedrock and groundwater conditions encountered during mining.

3.6.2.4 ALTERNATIVE 3B – REDUCED DIESEL BARGING: DIESEL PIPELINE

The expected effects of Alternative 3B are similar to those discussed under Alternative 2. The reduced barging of diesel fuel associated with Alternative 3B would reduce the exposure of groundwater to potential spills or leaks from diesel transport and storage systems along the

Kuskokwim River corridor and the mine access road from the Angyaruaq (Jungjuk) Port. Construction and operation of a diesel pipeline is expected to increase the risk of groundwater contamination from a pipeline spill or leak along the pipeline corridor (see Sections 3.24.6.7.2, Spill Scenarios and 3.7, Water Quality).

Based on terrain features from Beluga and Tyonek (Figure 2.3-40, Chapter 2, Alternatives), the occurrence of shallow groundwater along the ROW under Alternative 3B is expected to be roughly 4 miles longer than Alternative 2. An additional water well would be required at the operation center at Tyonek; however, the quantity of water used is expected to be only a small portion of the capacity of local or regional aquifers.

3.6.2.4.1 SUMMARY OF IMPACTS FOR ALTERNATIVE 3B

Direct and indirect effects for Alternative 3B would be mostly the same as discussed under Alternative 2. Impacts associated with climate change would also be the same as those discussed for Alternative 2. The implementation of Alternative 3B would have minor to moderate impacts on groundwater in the proposed Project Area.

Design features, Standard Permit Conditions and BMPs related to groundwater hydrology are described in Alternative 2. Additional mitigation and monitoring measures are also described in Alternative 2. If these mitigation measures were adopted and required, the summary impact rating would be similar to Alternative 2, minor to moderate, depending on actual bedrock and groundwater conditions encountered during mining.

3.6.2.5 ALTERNATIVE 4 – BIRCH TREE CROSSING PORT

The expected effects of this alternative are similar to those discussed under Alternative 2. The mine site and natural gas pipeline components are identical to Alternative 2; therefore, impacts would not change under Alternative 4.

Compared to Alternative 2, construction of a potable water well would be required at the BTC Port, and a water well would not be constructed at the Angyaruaq (Jungjuk) Port. The well would be constructed in compliance with State public well construction standards. A water rights or temporary water use authorization would be obtained complying with all permit conditions. The potable water well would be operated at the BTC Port for the duration of project operations. The quantity of water used would create low intensity impacts on groundwater resources, in that use levels would make up a small portion of the capacity of local or regional aquifers. These localized impacts would be considered long-term (lasting the duration of project operations), and would affect a common to important resource.

3.6.2.5.1 SUMMARY OF IMPACTS FOR ALTERNATIVE 4

Direct and indirect effects for Alternative 4 would be the same as discussed under Alternative 2. Impacts associated with climate change would also be the same as those discussed for Alternative 2. The implementation of Alternative 4 would have minor to moderate impacts on groundwater in the proposed Project Area.

Design features, Standard Permit Conditions and BMPs related to groundwater hydrology are described in Alternative 2. Additional mitigation and monitoring measures are also described in Alternative 2. If these mitigation measures were adopted and required, the summary impact rating would be similar to Alternative 2, minor to moderate, depending on actual bedrock and groundwater conditions encountered during mining.

3.6.2.6 ALTERNATIVE 5A – DRY STACK TAILINGS

3.6.2.6.1 MINE SITE

Option 1 – Unlined Dry Stack

Alternative 5A-Option 1 consists of placing tailings directly on a prepared overburden surface with coarse rock underdrains in the valley bottoms. An impermeable cap would be placed on the dry stack at closure. Under Option 1, groundwater from the valley slopes outside of the dry stack is predicted to flow into the tailings pile in the early operations phase. After 1-1/2 to 2 years, when seepage flow through the tailings begins to exit through the dry stack, the groundwater flow direction would change and flow away from the dry stack. At this point, tailings seepage could potentially reach groundwater beneath the dry stack, although the underdrains would be expected to continue to capture some if not all of the tailings seepage. At closure, placement of the impermeable LLDPE cover is predicted to decrease seepage rates through the tailings from about 78 gpm at the beginning of the closure period to about 18 gpm after 200 years, as porewater drains from the dry stack and very little new water infiltrates through the cover (BGC 2015d, Scenario 1).

Following removal of the operating pond and dam in post-closure, if contaminated groundwater is present in native materials beneath the dry stack or operating pond footprint, it would continue to migrate towards and be captured by the SRS and/or pumping wells, and report to the pit lake. Meanwhile, the supply of tailings porewater that could potentially feed the contaminant plume would be reduced by the impermeable cover, and seepage flow through the dry stack would gradually reduce to the same as that predicted under Alternative 2 (and Alternative 5A-Option 2) after 200 years. In other words, a contaminant plume, if present under Option 1, would eventually improve in quality to that of Alternative 5A–Option 2 and Alternative 2. Beyond 200 years, the amount of seepage flow under Option 1 is expected to continue its gradual decline as a result of the impermeable cover blocking infiltration of water to the flow system.

The SRS would include wells constructed similarly to those described under Alternative 2. The hydraulic containment system would consist of pumps in the seepage recovery pond, as well as pumping from four groundwater wells as needed. Whether or not the SRS could eventually be decommissioned after 200 years would be the same as under Alternative 2; i.e., continued SRS operation in perpetuity cannot be ruled out and there are provisions for these activities in Donlin Gold plans. As with Alternative 2, the capture and treatment of groundwater and seepage flow under both Alternative 5A options could lead to decreased concentrations of certain constituents in Crooked Creek compared to existing baseline conditions.

Option 2 – Lined Dry Stack

Under Alternative 5A-Option 2, tailings would be placed on top of an overdrain layer that is constructed over an impermeable LLDPE liner beneath the dry stack. The overdrain would be pumped to reduce mounding of the water table in the dry stack (BGC 2015d, Scenario 4). The overdrain water would not be pumped to the SRS; rather it would be pumped through a dedicated line back to the central mine area for plant operations, water treatment, or, after closure, to the pit lake. An impermeable cap would be placed on the dry stack at closure to limit infiltration into the dry stack. During operations and closure, the rate of seepage through the liner below the dry stack would be similar to Alternative 2 as a result of estimated leakage through the liner.

The potential loss of hydraulic containment of the SRS due to failure of pumping systems under both Alternative 5A options is similar to that described for Alternative 2, except that during the first 200 years or so following the end of mining under Option 1, larger volumes of water (up to about 80 gpm versus about 18 gpm under Alternative 2), would initially be expected to drain out of the tailings. The rate of water draining out of the dry stack would gradually decline during the period to the approximate amounts projected to leak through the liner under Alternative 2. Also, if hydraulic containment were lost during the early years of closure of Option 1, the quality of water released could be much poorer than under Alternative 2 because of the higher leakage rates from the dry stack and less dilution from the underdrain flows.

Climate Change

Impacts associated with climate change that are related to groundwater at the mine site under Alternative 5A are discussed in Section 3.26.4.6.2.

3.6.2.6.2 TRANSPORTATION FACILITIES

Impacts to groundwater resources associated with the construction, operations, and closure of the transportation facilities under Alternative 5A would be the same as discussed under Alternative 2.

3.6.2.6.3 NATURAL GAS PIPELINE

Impacts to groundwater resources associated with the construction, operations, and closure of the natural gas pipeline under Alternative 5A would be the same as discussed under Alternative 2.

3.6.2.6.4 SUMMARY OF IMPACTS FOR ALTERNATIVE 5A

The effects of the dry stack Alternative 5A-Options 1 and 2 on groundwater are expected to be similar to those of Alternative 2. Modestly more water (up to about 20 percent more) will require pumping and treating during the first 200 years of closure under Option 1 than under both Alternative 5A-Option 2 and Alternative 2. The amount of extra water would gradually decline to approximately the amount of water under Alternative 2. The extra water during the first 200 years of closure for Option 1 creates a slightly higher likelihood of groundwater contamination from pump failures and unplanned releases than Option 2; however, the difference is small and would not affect the summary impacts. Overall effects associated with climate change would be the same as those discussed for Alternative 2.

Design features, Standard Permit Conditions and BMPs related to groundwater hydrology are described in Alternative 2. Additional mitigation and monitoring measures are also described in Alternative 2. If these mitigation measures were adopted and required, the summary impact rating would be similar to Alternative 2, minor to moderate, depending on actual bedrock and groundwater conditions encountered during mining.

3.6.2.7 ALTERNATIVE 6A – MODIFIED NATURAL GAS PIPELINE ALIGNMENT: DALZELL GORGE ROUTE

For Alternative 6A, the proposed natural gas pipeline would follow an alignment through the Dalzell Gorge. Shallow groundwater conditions (Section 3.6.1.2.3) and impacts to shallow groundwater from pipeline construction and operations are expected to be substantially similar to those of the Alaska Range portion of Alternative 2. Based on geotechnical borehole and terrain mapping data (SRK 2012i), the Dalzell Gorge route would encounter about 1 mile less shallow groundwater than Alternative 2 (Figure 3.6-1). Thus, this modification would have the same direct and indirect effects to groundwater resources as Alternative 2 for the mine site, transportation facilities, and natural gas pipeline components of the proposed project. Impacts associated with climate change would also be the same as those discussed for Alternative 2.

Design features, Standard Permit Conditions and BMPs related to groundwater hydrology are described in Alternative 2. Additional mitigation and monitoring measures are also described in Alternative 2. If these mitigation measures were adopted and required, the summary impact rating would be the similar to Alternative 2 minor to moderate, depending on actual bedrock and groundwater conditions encountered during mining.

3.6.2.8 IMPACT COMPARISON – ALL ALTERNATIVES

A summary of impacts from Alternative 2 is presented in Table 3.6-4, and a comparison between alternatives is presented below in Table 3.6-5.

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Table 3.6-5: Comparison of Impacts by Alternative*

Impact-causing Project Component	Alt. 2 – Proposed Action	Alt. 3A – LNG-Powered Haul Trucks	Alt. 3B – Diesel Pipeline	Alt. 4 – BTC Port	Alt. 5A – Dry Stack Tailings	Alt. 6A – Dalzell Gorge Route
Mine Site						
Mine pit dewatering	Groundwater elevation change below original conditions: · 1,600 feet in operations; · 30 feet in post-closure. Groundwater flow direction changes: · Flow towards pit in perpetuity. Areal extent of cone of depression: · 9,000 acres in operations; · 2,000 acres in post-closure.	Mostly the same as Alternative 2, except reduced potential for diesel spill impacts.	Mostly the same as Alternative 2, except increased potential for diesel spill impacting groundwater.	Same as Alternative 2.	Similar to Alternative 2, except capture of up to about 20% more water during early closure period of Option 1, declining to equal amount of capture as Option 2 or Alternative 2 200 years after closure.	Same as Alternative 2.
Reduced or loss of wintertime flow in Crooked Creek	Range from average K-average flow to high K-low flow conditions:[1] · 20%-100% flow reduction near pit; · 10%-40% flow reduction 8 miles downstream.					
Capture and diversion of groundwater in Anaconda watershed	Under TSF and SRS: 450 gpm of groundwater is used for processing water in operations, and piped to pit lake after closure.					

Table 3.6-5: Comparison of Impacts by Alternative*

Impact-causing Project Component	Alt. 2 – Proposed Action	Alt. 3A – LNG-Powered Haul Trucks	Alt. 3B – Diesel Pipeline	Alt. 4 – BTC Port	Alt. 5A – Dry Stack Tailings	Alt. 6A – Dalzell Gorge Route
Transportation Facilities						
Groundwater usage at port sites.	Low intensity effect within aquifer capacity and on other users.	Mostly the same as Alternative 2. Slight reduced potential for diesel spill impacts from a reduction in fuel barge trips from 58 to 19 per season along the Kuskokwim River.	Mostly the same as Alternative 2, except decreased potential for diesel spill impacting groundwater.	Mostly the same as Alternative 2 except translocation of port water well; slight increased potential for trucking-related spill as a result of longer road.	Same as Alternative 2.	Same as Alternative 2.
Pipeline						
Groundwater usage at camps.	Low intensity effect within aquifer capacity and on other users.	Same as Alternative 2	Mostly the same as Alternative 2, except increased potential for diesel spill impacting groundwater and shallow groundwater 4 miles > Alt. 2.	Same as Alternative 2.	Same as Alternative 2.	Mostly the same as Alternative 2 (shallow groundwater 1 mile < Alt. 2).
Potential diversion of groundwater during construction or operations.	Low intensity, localized effect on shallow groundwater beneath 112 miles (1/3rd) of ROW.					
Summary Impact Conclusion	Minor to Moderate (depending on uncertainties[2])	Same as Alternative 2.	Same as Alternative 2.	Same as Alternative 2.	Same as Alternative 2.	Same as Alternative 2.

Notes:

1 Data are from Table 3.5-26, Surface Water Hydrology.
2 Based on range of results from groundwater model sensitivity runs.

* Alternative 1 (No Action Alternative) would have no impacts to groundwater hydrology.
K = hydraulic conductivity